INTRODUCTION TO SCIENCE

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CHAPTER I

THE SCIENTIFIC MOOD

"For myself I found that I was fitted for nothing so well as for the study of Truth; as having a mind nimble and versatile enough to catch the resemblance of things (which is the chief point), and at the same time steady enough to fix and distinguish their subtler differences; as being gifted by nature with desire to seek, patience to doubt, fondness to meditate, slowness to assert, readiness to reconsider, carefulness to dispose and set in order; and as being a man that neither affects what is new nor admires what is old, and that hates every kind of imposture. So I thought my nature had a kind of familiarity and relationship with Truth."—FRANCIS BACON.

Before Science—The Practical Mood—The Emotional Mood—The Scientific Mood contrasted with the Others—Adjustment of Moods—Characteristics of the Scientific Mood—A Passion for Facts—Cautiousness of Statement—Clearness of Vision—Sense of the Inter-relatedness of Things—Culture of the Scientific Mood—Summary.

BEFORE SCIENCE.—We do not know much that is quite certain in regard to our early ancestors,

but it is safe to say that man's relations with Nature were for a long time predominantly practical. We may recall the vivid picture which Æschylus gives of primitive men—living in caves, without fire, without wood-work, without system, without seasons, without foresight, a dream-life without science:—

"And let me tell you, not as taunting men,
But teaching you the intention of my gifts
How, first, beholding they beheld in vain,
And, hearing, heard not, but like shapes in dreams,
Mixed all things wildly down the tedious time,
Nor knew to build a house against the sun
With wicketed sides, nor any wood-work knew
But lived like silly ants, beneath the ground,
In hollow caves unsunned. There came to them
No steadfast sign of winter, nor of spring
Flower-perfumed, nor of summer full of fruit,
But blindly and lawlessly they did all things,
Until I taught them how the stars do rise
And set in mystery, and devised for them
Number, the inducer of philosophies,
The synthesis of letters, and besides
The artificer of all things, Memory
That sweet muse-mother."

In those early days the various moods that we are familiar with—such as the scientific, the artistic, and the philosophic—had not become defined off from an oppressive practical mood. Very gradually, however, Man got a firmer foothold in the struggle for existence, and was able to raise his head and look at the stars. He discovered the year with its marvellous object-lesson of recurrent sequences—a discovery which was one of the first great steps towards science, and he became vividly aware that his race had a history. He had time, too, for a conscious enjoyment of Nature, which came to mean more and more to him. Here and there, perhaps, some began to ponder over the significance of their experience. Gradually, at all events, as the ages passed, various moods became, as we say, differentiated from one another, and men began to be contrasted according as this or that mood was more habitual with them. Men of action, men of feeling, and men of thought, these were the three primary types, which are now-a-days split up into minor types. They correspond, obviously, to doing, feeling, and knowing; to hand, heart, and head; to practice, emotional activity, and intellectual inquiry. That we may better understand the scientific mood, let us consider for a little the others.

The Practical Mood.—First there is the

mood of the dominantly practical man, whose whole trend is towards doing, not towards knowing. He must, of course, know his facts if his doings are to be effective, and he must, likewise, have sound social feeling if his doings are to be deeds, not misdeeds; and no one will seek to dispute that the practical man has a firm grip of facts, and that he is often full of that kindliness which marks a strong development of the kin-instinct. Yet he himself would be the first to point out that he had no particular hunger or thirst after the descriptive formulæ which Science seeks to supply. So far as Science means that kind of knowledge which is Foresight, that kind of Foresight which is Power, he believed in it; but on the whole it did not interest him. Similarly, while he would confess to a pleasure in friendly relations between man and man, and between man and his beasts, and to a sometimes apparently hyperæsthetic sense of order, he would admit, on the whole, that æsthetic emotion was not much in his line. He was not built that way.

There is obviously much to be said for the dominant practical mood. It is as natural and necessary and dignified as any other. Science grew out of practical lore, and fresh vigour has often come to science by a tightening of its touch with the business of everyday life. How much mathematics, for instance, both simple and subtle

has arisen in direct response to practical needs, whether of measuring land or measuring electricity!

On the other hand, the risks of a tyrannous practical mood are great. When things get into the saddle and override ideas and ideals and all good feeling, when the multiplication of loaves and fishes becomes the only problem in the world, we know the results to be vicious. To be wholly practical is to grub for edible roots and see no flowers upon the earth, no stars overhead. The exaggeratedly practical man "will have nothing to do with sentiment," though he prides himself in keeping close to "the facts"; he cannot abide "theory," though he is himself imbued with a quaint Martin Tupperism which gives a false simplicity to the problems of life; he will live, he insists, in "the real world," and yet he often hugs close to himself the most unreal of ideals.

The Emotional Mood.—Secondly, there is the emotional and artistic mood, which finds expression in Schiller's words: "O wunderschön ist Gottes Erde, und schön auf ihr ein Mensch zu sein." "Oh wondrous beautiful is God's earth, and good it is to be a man upon it."

From man's first emergence, perhaps, the herbs and the trees, the birds and the beasts, sent tendrils into his heart, claiming and finding kinship. Ever so early there must have been a

rude joy in the heavens and the earth, and in the pageant of the seasons—something more than the pleasure of basking in the sun like a lizard. Probably, however, it was not until man had gained some firmness of footing in the world, secured by his wits against stronger rivals and a careless environment, that the emotional tone grew into dignity as a distinct mood, a genuine enjoyment of beautiful things, which found expression in music and dance, in song and story, in painting and carving, and in religious rites.

Like the practical mood, so the emotional mood has its obvious virtues. It is part of the salt of life. It begets a sympathy that is insight. In a noisy world it helps to keep us aware of harmony hidden in the heart of things.

We are perhaps apt to think too lightly of the value of the more primitive æsthetic emotions. Do we not need some infusion of the simple delight in the earth which was expressed for instance by Matthew Arnold in his *Empedocles on Etna:* "Is it so small a thing to have enjoy'd the sun?" There is a fine ideal, which no science need contradict, in that line of Goldsmith's: "His heaven commences ere the world be past." It is only by the culture of the emotional mood—though the words are almost self-contradictory—that man "hitches his wagon to the stars."

But, just as with any other disproportionate evelopment, there are risks in the hypertrophied motional mood. Uncurbed by science, un-elated to practice, it may become morbid, even ad. Rational wonder may degenerate into "a aterwauling about Nature." Enthusiasm for hat is beautiful, without relevant activity, may ecome an unpleasant effervescence. There may e overfeeling, just as there may be overdoing.

The Scientific Mood contrasted with the thers.—The scientific worker has elected pri-arily to know, not do. He does not *directly* seek, ke the practical man, to realize the ideal of xploiting nature and controlling life—though he akes this more possible; he seeks rather to lealize—to conceptualize—the real, or at least ose aspects of reality that are available in his xperience. He thinks more of lucidity and rmulæ than of loaves and fishes. He is more ncerned with knowing Nature than with en-ying her. His main intention is to describe e sequences in Nature in the simplest possible rmulæ, to make a working thought-model of e known world. He would make the world anslucent, not that emotion may catch the mmer of the indefinable light that shines rough, but for other reasons—because of his born inquisitiveness, because of his dislike of scurities, because of his craving for a system—

an intellectual system in which phenomena ar at least provisionally unified.

And, as we have indicated the vices of an exaggerated emotional mood and of a too exclusivel practical mood, so we must admit that th hypertrophied scientific mood has its risks,—o ranking science first, and life second (as if scienc were not, after all, for the evolution of life); o ignoring good feeling (as if knowledge could no be bought at too high a price); of pedantry (a if science were merely a "preserve" for the expert intellectual sportsman, and not also a education for the citizen); of disproportionat analysis—dissecting more than it reconstructs— so that the artistic perception of unity and harmony is lost; of maniacal muck-raking for item of fact (as if facts alone constituted a science).

Adjustment of Moods.—Before we go on t consider the characteristics of the scientific moo in greater detail, let us sum up so far. There ar three dominant moods in man—practical, emotional, and scientific—each with its subdivision They correspond symbolically to hand, heart, an head, and they are all equally necessary an worthy. "And the eye cannot say unto th hand, I have no need of thee: nor again the hea to the feet, I have no need of you." They ar all worthy, but most so when they respect on another as equally justifiable outlooks on natur

and when they are combined, in adjusted proportions, in a full human life. But that is so difficult of attainment, especially when great excellence in one direction has been inherited or acquired, that the disproportionate developments we have spoken of are apt to occur. They are often the more dangerous because of the very strength which the exaggeration gives to its possessor. This is part of the penalty of genius.

For ordinary folk, however, it is safe to say that when any mood becomes so dominant that the validity of the others is denied or ignored, the results are likely to be tainted with some vice —some inhumanity, some sentimentalism, some pedantry, some violence to the unity of life. A sane life implies a practical recognition of the trinity of knowing, feeling, and doing. This spells health, wholeness, holiness, as Edward Carpenter has well said.

Characteristics of the Scientific Mood.—In his presidential address to the British Association in 1899, Sir Michael Foster inquired into the qualities that distinguish the scientific worker, and came to the conclusion that they were, in the main, three:—

"In the first place, above all other things, his nature must be one which vibrates in unison with that of which he is in search; the seeker after truth must himself be truthful, truthful with

the truthfulness of nature; which is far more imperious, far more exacting than that which man sometimes calls truthfulness.

"In the second place, he must be alert of mind. Nature is ever making signs to us, she is ever whispering to us the beginnings of her secrets; the scientific man must be ever on the watch, ready at once to lay hold of Nature's hint, however small, to listen to her whisper, however low.

"In the third place, scientific inquiry, though it be pre-eminently an intellectual effort, has need of the moral quality of courage—not so much the courage which helps a man to face a sudden difficulty as the courage of steadfast endurance."

Anticipating the obvious criticism that these three qualities of truthfulness, alertness, and courage are not in any way peculiar to the scientific man, but "may be recognized as belonging to almost every one who has commanded or deserved success, whatever may have been his walk in life," Sir Michael said: "That is exactly what I would desire to insist, that the men of science have no peculiar virtues, no special powers. They are ordinary men, their characters are common, even commonplace. Science, as Huxley said, is organized common-sense, and men of science are common men, drilled in the ways of common sense."

Perhaps this protests a little too much, that the scientific man is as other men are, but it emphasizes a useful point, that the scientific mood does not necessarily imply any particular knowledge of this or that science. Some men who are quite ignorant of any of the concrete sciences have nevertheless a highly developed scientific mood. Give them data and a clearly stated problem, and they soon show that they are scientific in every fibre of their mind. It is indeed a vulgar error that science is anything by itself. To speak of "going in for science" is like proposing to go in for breathing or good digestion.

When all is said, however, we feel that there *is* something distinctive in the scientific mood, and this requires further analysis. It will appear that our conclusions agree with Sir Michael Foster's, but they emphasize intellectual rather than moral features.

A Passion for Facts.—As a first characteristic of the scientific mood we would rank a passion for facts, which corresponds to the quality of truthfulness in Sir Michael Foster's analysis. It is the desire for accuracy of observation and precision of statement. "First make sure of the facts," is a fundamental precept in science, but it is no easy matter. Even in regard to simple problems it is often difficult to get a grip of the facts of the case. Even in regard to simple oc-

currences it is often difficult to give a quite accurate account of what took place. This is partly due to the dash of the artistic mood which most men have. It is often due to the untrained eye, which sees only what it has the power of seeing,—sometimes little indeed—and, in the opposite direction, to preconceptions which often enable men to see what is not to be seen. It is also due to lack of discipline in the method of science; thus nothing is commoner than a narration that mingles observation with unconscious inferences from observation, which is one of the elementary fallacies.

"Man, unscientific man," Sir Michael Foster said, "is often content with 'the nearly' and 'the almost.' Nature never is. It is not her way to call the same, two things which differ, though the difference may be measured by less than the thousandth of a milligramme or of a millimetre, or by any other like standard of minuteness. And the man who, carrying the ways of the world into the domain of science, thinks that he may treat Nature's differences in any other way than she treats them herself, will find that she resents his conduct; if he in carelessness or in disdain overlooks the minute difference which she holds out to him as a signal to guide him in his search, the projecting tip, as it were, of some buried treasure, he is bound to go

astray, and, the more strenuously he struggles on, the farther will he find himself from his true goal."

Many children seem to pass through an interesting stage in which they fail to discriminate between their dream-pictures and their wide-awake pictures of actual occurrences, and it was probably ingenuousness rather than any lack of good faith that led some of the old naturalist-travellers, in the glamour of strange lands, to mix up in their diaries what they actually saw and what the natives told them was to be seen. And we do not need to go back to ancient history to find examples.

The scientific worker is well aware that in measurements and observations the accuracy attainable is only approximate, and that the degree of approximation varies with the individual. The personal equation has been for a long time frankly recognized and allowed for in astronomy; it is also sometimes estimated in chemistry and physics; but it must be recognized all round. Science begins with measurement and there are some people who cannot be measurers; and just as we distinguish carpenters who can work to this or that fraction of an inch of accuracy, so we must distinguish ourselves and our acquaintances as able to observe and record to this or that degree of truthfulness.

Hence, naturally, the importance of discipline and apprenticeship in precision—whether with the chemical balance or with the scalpel, with the sextant or the micrometer. Even faithful drawing is an effective factor in the development of truthfulness; and we heartily agree with Agassiz that a training in natural science is one of the best preparations a man can have for work in any department of life where accurate carefulness and adherence to the facts of the case are of indispensable importance.

Long ago Bacon said: "We should accustom ourselves to things themselves," and this—to distinguish between appearance and reality—is what the scientific mood seeks after. Its emblem might be the X-rays which penetrate through superficial obscurities. It is the note of precision that is distinctive. We read of Clerk Maxwell: "Throughout his childhood his constant question was, 'What's the go of that? What does it do?' Nor was he content with a vague answer, but would reiterate, 'But what's the *particular* go of it?'"

The quality of accuracy has, of course, a great variety of expressions at many different levels, but it is of the same mood and towards the same ideal all through. The discipline of weighing and measuring is doubtless sometimes exaggerated into an end in itself, and made unnecessarily

tedious by its unrelatedness to real problems, but those who are inclined to be impatient with it should remember that it is congruent with and contributory to "that enthusiasm for truth, that fanaticism of veracity, which is a greater possession than much learning; a nobler gift than the power of increasing knowledge."

These are Huxley's words, whose passion for facts marked all he said and did. They suggest a famous sentence in his autobiography, in which he expressed his aims in life. "If I may speak of the objects I have had in view since I began the ascent of my hillock, they are briefly these: To promote the increase of natural knowledge and to forward the application of scientific methods of investigation to all the problems of life to the best of my ability, in the conviction which has grown with my growth and strengthened with my strength, that there is no alleviation for the sufferings of mankind except veracity of thought and of action, and the resolute facing of the world as it is, when the garment of make-believe by which pious hands have hidden its uglier features is stripped off."

We have used the strong phrase "a passion for facts" because of the intensity which all the great masters in science have shown in their reverence for truth and in their contempt for mere opinions. "Opinions," Glanville says, "are

the rattles of immature intellects, but the advanced reasons have outgrown them."

"The longer I live," Huxley said, "the more obvious it is to me that the most sacred act of a man's life is to say and feel, 'I believe such and such to be true.' All the greatest rewards and all the heaviest penalties of existence cling about that act."

Cautiousness of Statement.—Following from the passion for facts, there is a second characteristic of the scientific mood, namely, cautiousness. It has habituated itself to withhold judgment when the data are obviously incomplete; to doubt conclusions that have been quickly reached; to hesitate in accepting what is particularly attractive whether in its simplicity or its symmetry. Thus scientific workers are naturally sceptical and of the school of St. Thomas—which is in no way inconsistent with a tenacity of conviction when the demonstration is complete. Not any easier than accuracy is this quality of active scepticism, "thätige Skepsis." Indeed, as Prof. W. K. Brooks says in his *Foundations of Zoology:* "The hardest of intellectual virtues is philosophic doubt, and the mental vice to which we are most prone is our tendency to believe that lack of evidence for an opinion is a reason for believing something else." . . . "Suspended judgment is the greatest triumph of intellectual

discipline." The sceptical, distrustful, scientific desire to test everything was charmingly hit off in the definition of a professor given in *Fliegende Blätter*—"Ein Professor ist ein Mensch der anderer Meinung ist." "A professor is a man who is of a different opinion."

It is true that the scientific mood is continually making hypotheses or guesses at truth; the scientific use of the imagination is a recognized method. It is a kind of intellectual experimentation, and it suggests actual experiments by which it is itself tested. The danger of this is not so much for experts as for those who have incomplete mastery of the rules of the game, but every one will admit that provisional hypotheses have a tendency to put on the garb of full-grown theories, or even of established doctrines. As Mr. Bateson has phrased it, the controlled scientific mood will avoid "giving to the ignorant as a gospel, in the name of science, the rough guesses of yesterday that to-morrow should forget." As Huxley said with memorable severity: "The assertion that outstrips the evidence is not only a blunder but a crime."

A fine illustration of scientific restraint is to be found in Huxley's agnostic position in regard to the theory of evolution *before* the publication of the *Origin of Species.* He had studied Lamarck attentively, and he had fought many and pro-

longed battles with Herbert Spencer on the subject. "But even my friend's rare dialectic skill and copiousness of apt illustration could not drive me from my agnostic position. I took my stand upon two grounds: Firstly, that up to that time, the evidence in favour of transmutation was wholly insufficient; and secondly, that no suggestion respecting the causes of transmutation assumed, which had been made, was in any way adequate to explain the phenomena. Looking back at the state of knowledge at that time, I really do not see that any other conclusion was justifiable." . . . "That which we were looking for, and could not find, was a hypothesis respecting the origin of known organic forms which assumed the operation of no causes but such as could be proved to be actually at work. We wanted, not to pin our faith to that or any other speculation, but to get hold of clear and definite conceptions which could be brought face to face with facts and have their validity tested. The *Origin* provided us with the working hypothesis we sought." . . . "The only rational course for those who had no other object than the attainment of truth was to accept 'Darwinism' as a working hypothesis and see what could be made of it. Either it would prove its capacity to elucidate the facts of organic life, or it would break down under the strain." (See Huxley's *Life and*

Letters, vol. i. p. 168.) To read these words is to breathe the scientific atmosphere. They illustrate the scientific mood better than any analysis.

Cautiousness, then, is characteristic of science. Just as "burnt bairns dread the fire"; so the scientific mood, often deceived by misobservation, by inferences mixed up with records, by hearsay evidence, by an induction from too narrow a basis, and even by the will-o'-the-wisp glamour of a brilliant hypothesis, becomes more and more cautious, distrustful, "canny." One of the forms of cautiousness that is most difficult of attainment, and yet indispensable, is distrust of our personal bias in forming judgments. Our interpretations are necessarily coloured by our personal experience and our social environment; our hypotheses may arise from social suggestion: but before they pass into the framework of science they must be "de-personalized." In fact, the validity of a scientific conclusion, as distinguished from a mere opinion, depends on the elimination of the subjective element. As Prof. Karl Pearson says: "The scientific man has above all things to strive at self-elimination in his judgments, to provide an argument which is as true for each individual mind as for his own. The classification of facts, the recognition of their sequence and relative significance, is the function of science, and the habit of forming a

judgment upon these facts, unbiassed by personal feeling, is characteristic of what may be termed the scientific frame of mind" (*Grammar of Science*, 1900 edition, p. 6).

As Faraday said: "The world little knows how many of the thoughts and theories which have passed through the mind of a scientific investigator have been crushed in silence and secrecy by his own severe criticism and adverse examination; that in the most successful instances not a tenth of the suggestions, the hopes, the wishes, the preliminary conclusions have been realized." As a complementary statement we give another quotation from the same great authority: "The philosopher should be a man willing to listen to every suggestion, but determined to judge for himself. He should not be biassed by appearances; have no favourite hypotheses; be of no school, and in doctrine have no master. He should not be a respecter of persons, but of things. Truth should be his primary object. If to these qualities be added industry, he may indeed hope to walk within the veil of the Temple of Nature."

It seems to us strange that some biologists have criticized Prof. Weismann because in the course of a quarter of a century or more, he has modified certain of his suggestions as new facts came within his knowledge. Nothing is more

characteristically scientific. As Prof. J. H. Poynting has admirably put it: "The hypotheses of science are continually changing. Old hypotheses break down and new ones take their place. But the classification of known phenomena which ✓ a hypothesis has suggested, and the new discoveries of phenomena to which it has led, remain as positive and permanent additions to natural knowledge when the hypothesis itself has vanished from thought."

Clearness of Vision.—A third characteristic of the scientific mood is the endeavour after clearness, the dislike of blurred vision and obscurities. The mole has a sort of half-finished lens, which is physically incapable of throwing any clear image on the retina. If there is any image at all, it must be a blurred tangle of lines. In our busy lives, as the nemesis of our specialisms and pre-occupations, we tend to have moles' lenses in regard to particular orders of facts; we see certain things clearly, but others are blurs. The scientific mood is in continual protest against this; it is all for clearness.

When we work long at a thing and come to know it up and down, in and out, through and through, it becomes in quite a remarkable way translucent. The botanist can see through his tree, see wood and bast, cambium and medullary rays, all in their proper place; he can see the

ascending water and salts, the descending sugar and proteids. The zoologist can in the same way see through the snail on the thorn, seeing as in a glass model everything in its place, the nerve-centres, the muscles, the stomach, the beating heart, the coursing blood, and the filtering kidney. So the human body becomes translucent to the skilled anatomist, and the globe to a skilled geographer.

Similarly, on a higher plane than merely optical clearness, those of the scientific mood are in great part trying to make the world translucent. They are seeking to construct an intellectual cinematograph of the long processions of causes that pass unceasingly before us. A perfectly clear working thought-model is what science seeks to construct.

There is so much to know that ignorance in itself is no particular reproach; but the point is to be clear when we know and when we do not, and it is one of the characteristics of the scientific mood that it will have yes or no to this question.

"Do you see it or do you not?" was the continual question of a biological teacher gifted with great educational ability, and "If you see it, what is it like?"

A student who worked under Agassiz relates how she was almost brought to despair by the severe way in which that great master, after giv-

ing her a specimen to study, came day after day, and asked, with a cruel kindliness: "Well, what do you see now?" and then went away. But at length the student saw something—saw what was to be seen, and more also.

What science knows it must know definitely; what it sees must be in focus. It feels the wisdom of one of Bacon's aphorisms—often verified in history: "Truth to emerge sooner from error than from confusion." The definitizing of error is often the beginning of its disappearance. When the evil genie of the Eastern tales took on definite bodily form there was some chance of tackling him; as a mere wraith he was unassailable.

One of the expressions of the scientific endeavour after clearness is to be found in precision of speech. Thus Prof. Silvanus P. Thompson says of Lord Kelvin: "He hated ambiguities of language, and statements which mislead by looseness of phrasing. With painful effort he strove for clarity of expression, elaborating his phrases in a way that threatened at times to defeat the end intended. In that hazy medium of words wherein we all drown, he at least would attempt to observe the proprieties of language. As an example take this: Externally the sense of touch, other than heat, is the same in all cases—it is a sense of forces, and of places of application of forces, and of directions of forces."

Sense of the Inter-relatedness of Things.—A fourth characteristic of the scientific mood is a sense of the inter-relatedness of things. It regards Nature as a vibrating system most surely and subtly interconnected. It discloses a world of inter-relations, a long procession of causes, a web of life, infinite sequences bound by the iron chains of causality.

In illustration, we would quote what we have said elsewhere in reference to Darwin's picture of "The Web of Life,"—one of the grandest of all scientific pictures. "What is meant by Darwin's picture of the Web of Life, and where did he paint it? We find it in all his works—a luminous background—the idea of linkages in nature, the idea of the correlation of organisms. Cats have to do with the clover-crop, Darwin says, and earthworms with the world's bread supply. If there is an orchid in Madagascar with a spur eleven inches long, Darwin prophesies that there is a moth with a proboscis of equal length. No bird falls to the ground without sending a throb through a wide circle, for Darwin rears eighty seedlings from a single clod taken from a bird's foot. Long nutritive chains may bind the bracken on the hill-side to the brain of the proprietor—if he is fond of eating trout. The patent-leather shoes on his feet connect him with the melancholy slaughter of seals, while his ivory-backed

toilet-brushes implicate him in the passing of the elephant. There is a ceaseless circulation of matter and energy. All things flow. Influence passes from A. to Z., though Z. is quite unaware of A. What ripples spread and spread from the introduction of rabbits into Australia, or of sparrows into the United States, or of the mongoose into Jamaica. What absolutely essential connections there are between cutting down trees and a plague of insects, between birds and seed-scattering, between sunlight and the catches of mackerel" (*Darwinism and Human Life*, 1909, p. 10). These and hundreds of similar linkages seem at first quaint puzzles, but when the house-that-Jack-built procession of causes is indicated, they become clear as daylight—as actualities of inter-relatedness. Our illustrations happen to be biological, but the idea is universal, and the outlook for all sorts of inter-relations in the great system of nature is diagnostic of the scientific mood. It is often seen in high development in men of business, particularly in those who have geographical interests. For it must be borne in mind throughout that the scientific mood is in no way confined to those who pursue science in the stricter sense.

Culture of the Scientific Mood.—We do not apologize for giving so much prominence to an elementary discussion of the chief charac-

teristics of the scientific mood. For in a series like that to which this volume belongs it cannot be made too clear that science is no "preserve" for the learned, but the birthright of all. We must never think of it as something printed and ponderous and more or less finished, but as something living in our mind and influencing our work.

As was admirably said by Mr. Benchara Branford in an address to students: "Science is born anew in the deliberate will and intention of each of us when we succeed in thinking about the principles of our work in a clear, logical, and systematic way, and courageously put our conclusions to the test of experiment; and the so-called sciences are the written records of such thinking, only more extensive, clear, systematic, and consistent, and more true to reality, because they have been tested by countless experiments and experiences in the race."

What would one not give to be able to tell how the scientific mood may be developed! Our inheritances are diverse and unequal, and they limit us; yet much can be gained by "nurture" and much lost for the lack of it.

A born raconteur is not likely to make a good man of science even in the best laboratory in the world, and a man without a dash of poetry is not likely to acquire it by a diligent perusal

of the *Faërie Queene*, yet it is idle to pretend that we cannot to some extent influence the development of our inherited moods by appropriate nurture.

By dint of hammering, one becomes a smith, and it is by doing scientific work that one cultivates the scientific habit of mind. Those who mean to become teachers and investigators may find inspiration in being apprenticed to a great master and in a laboratory with great traditions; those who mean only to become intelligent citizens of the world—to whom this volume, with the rest of the Library, is primarily addressed—may find inspiration in reading scientific "classics," histories of science (astronomy, best of all), and biographies of the great masters (such as Faraday, Clerk Maxwell, Helmholtz, Kelvin, Huxley, Darwin, and Pasteur), *but the scientific temper must be wrought out by each one for himself.*

What we wish to make clear is that the scientific mood does not necessarily demand for its development the long sea-voyages that meant so much to Darwin and Huxley, nor the extensive explorations and long solitudes that meant so much to Humboldt and Wallace, nor dramatic opportunities such as came to Pasteur, nor splendidly equipped laboratories, nor costly instruments.

What is demanded is within the reach of all

who will habituate themselves in making sure of the facts, in precision of statement, in getting things clear, and in realizing the complexity of all situations. These qualities cannot be acquired passively; the kingdom of science must be taken by force. The scientific mood can only be engendered by our being actively and energetically scientific.

It matters little what problem is tackled, but it should, at first, be one that admits of discipline in some form of measurement or accurate registration. It is often well to follow our tendrils of spontaneous interest towards some subject which naturally attracts us; but it is also well that we should undertake some difficult piece of work, which stretches our brains. In some way those who would develop the scientific mood must learn to endure hardness intellectually, remembering Darwin's recipe: "It's dogged that does it."

SUMMARY.—*The scientific mood is especially marked by a passion for facts, by cautiousness of statement, by clearness of vision, and by a sense of the inter-relatedness of things. It is contrasted with the emotional or artistic mood and with the practical mood, but the three form a trinity (of knowing, feeling and doing), which should be unified in every normal life.*

CHAPTER II

THE AIM OF SCIENCE

"The classification of facts, the recognition of their sequence and relative significance is the function of science, and the habit of forming a judgment upon these facts unbiassed by personal feeling is characteristic of what may be termed the scientific frame of mind."—KARL PEARSON.

Observation, Description, and Formulation—Science and Common-Sense—The Subject-Matter of Science—Descriptive Character of Science—Knowledge of Causes—Reduction to Simpler Terms—Laws of Nature—Particular Aims of Different Sciences—The Evolutionary Aim—Summary.

LONGSTANDING controversies regarding science and religion, science and theology, science and philosophy, science and poetry, owe their longevity partly to a misunderstanding of *the aim of Science.* We propose, therefore, to devote a chapter to this subject, which is also of great interest for its own sake.

OBSERVATION, DESCRIPTION, FORMULATION.—The primary aim of Science is the concise description of the knowable universe. The man of

scientific mood becomes aware of certain facts that interest him; he proceeds to become more intimately aware of them; to make his sensory experience of them as full as possible. Careful and critical observation is the first step.

This work of Science, which we may call getting at the facts, is much more difficult of attainment than those who have not tried imagine. One reason for this is very familiar,—that things are not always what they seem to be. And though Science does not raise the characteristic metaphysical question as to what is meant by being *real*, it has in its own way to distinguish seeming from reality. The sun does not rise and set, the stable Earth is a whirling sphere, the inert body may be a vortex of rapidly moving corpuscles, and so on. If Science is to be consistent it has to set itself to the task of distinguishing realities from appearances.

Having got his facts, the scientific investigator proceeds to arrange them, to find their common denominator, to discover the conditions of their occurrence, and to describe them as completely and as simply as possible, and finally to sum them up in a general formula, often called "a law of nature."

Aristotle defined this aim when he said: "Art [or, as we should say, Science] begins when, from a great number of experiences, one general con-

ception is formed which will embrace all similar cases." And the greater part of the clearing-up which Science effects is not in forming some new general conception, but in bringing new sets of facts within the grasp of an old one. When we make things more intelligible, we do so by discerning the general beneath the particular, the "permanent law" beneath the "evanescent circumstance."

In short, it is the aim of Science to describe the impersonal facts of experience in verifiable terms, as exactly as possible, as simply as possible, and as completely as possible. It is an intellectual construction—a working thought-model of the world. In its universe of discourse it keeps always to experiential terms or verifiable symbolical derivates of these.

Science and Common-Sense.—It is somewhat remarkable that several investigators of distinction have compared Science to common-sense. We are told that "A most simple description of true science is embraced in the words: Keep your eyes open and apply common-sense." Prof. P. G. Tait was wont to say that Science aims at giving "a common-sense view of the world we live in." Huxley emphasized the idea that "Science is nothing but trained and organized common-sense."

It seems to us that it would be nearer the truth

to say that Science is sharply contrasted with common-sense. Thus one of the most marked characteristics of science is its critical quality, which is just what common-sense lacks. By common-sense is usually meant either the consensus of public opinion, of unsystematic everyday thinking, the untrustworthiness of which is notorious, or the verdict of uncritical sensory experience, which has so often proved fallacious. It was "common-sense" that kept the planets circling round the earth; it was "common-sense" that refused to accept Harvey's demonstration of the circulation of the blood.

THE SUBJECT-MATTER OF SCIENCE.—We have already pointed out that Science is independent of any particular order of facts. It takes the knowable universe for its subject; it deals with psychical as well as physical processes, with Man as much as with Nature; it has to do with everything *to which its methods can be applied.* What makes a study scientific is not, of course, the nature of the things with which it is concerned, but the *method* by which it deals with these things. A study of a skylark is not necessarily zoological.

The subject-matter of Science includes all clearly defined facts of experience which are communicable and verifiable. There are three points here to be attended to. (1) Before Science

really begins, a preliminary sifting is often necessary to distinguish supposed facts seen by the untutored eye from clearly defined facts. (2) The facts that Science takes to do with are "real," and "what is real means something which we do not *make*, but *find*." As Thomas Hobbes of Malmesbury said in his great *Leviathan* (1651): "Natural History is the history of such facts or effects of nature as have no dependence on man's will." (3) Only one self-denying ordinance has Science imposed on itself in regard to its subject-matter. The ordinance is that Science shall consist only of the communicable and verifiable. However real certain personal experiences may be to us, we are restrained by boundaries of our own erection from calling these experiences scientific territory. They may be, but they are not until it is shown that similar personal experiences will be enjoyed by all who place themselves in the appropriate conditions.

Descriptive Character of Science.—When the aim of Science is spoken of as "description" the word is used in a slightly technical sense. There is a preliminary description which is not more than a faithful record of observations—the kind of description which Linnæus, for instance, excelled in giving for a species of plant or animal. But this is only intellectual photography,

good, but only a means to an end,—to a higher kind of description which is characteristically scientific.

When we say that the object of Science is "the complete and consistent description of the facts of experience in the simplest possible terms," we are adopting a view—held by such authorities as Kirchhoff, Mach, Karl Pearson, and Ward—which is to many minds disappointing. Description seems such a tame term to apply to the function of Science, which, we are told, is to solve the riddles of the universe.

When we come to think it over, however, or better still, when we try to work it out, "a complete and consistent description in the simplest possible terms" is no small achievement. It must leave nothing out, it must be consistent with itself, with the rest of the science of which it forms a part, with Science as a whole, with the formal conditions of experience in general. Of a truth, "complete and consistent description" will tax our intellectual thews and sinews. And it must be in the simplest possible terms, which means penetrating analysis, careful reduction to the lowest common denominator. And the terms must be such as are accessible to direct experience or to indirect experimental testing. Such is the aim of Science.

Behind the first feeling of disappointment

with the definition of Science as a description of the facts of experience, there lurks a second: Is the *explanation* of things to be given up? Is it not the office of Science to get behind description and to supply explanation? The answer to that question is this: (*a*) The vulgar belief that Science has "explained everything" is a hopeless misunderstanding. As we shall afterwards find, it would be nearer the truth to say that Science has explained nothing. (*b*) Science does not even try to refer facts of experience to any ultimate reality. That is not its business. (*c*) In a limited sense Science explains things, namely, by reducing them to simpler terms, by discovering the conditions of their occurrence, and by disclosing their history. What do we mean when we say that Physics has accounted for the tides, or that Physiology has made some function of the body much more intelligible than it used to be? What is meant is that we have gained a general conception of the nature of the facts in question, and that we are able to relate them to some general formula. In this sense only does Science explain things, and it does not really get beyond a description.

Knowledge of Causes.—We must admit that there is good sense in the popular impression that it is the aim of Science to discover the causes of things. What is Science for if it does

not make our experience of the world around us and of ourselves more intelligible, and does not this increased intelligibility depend in great part on the discovery of causes? Science has been defined, indeed, by a distinguished physiologist, Prof. Gotch, as "the causative arrangement of phenomena."

But how is this consistent with the descriptive view of Science? We have seen that Science does not "explain" anything. But what else is the discovery of causes?

To answer this question involves a brief digression into a difficult and dangerous territory,—*the meaning of cause.* The first point that we must be clear about is that in the natural sciences, the causes which are discovered are "secondary" or "caused causes," the question of ultimate causes not being raised; and that they are "efficient," not "final" causes, not giving any answer to the question "Why?" In the natural sciences the word cause is used in the sense indicated by Mill,—"a cause which is itself a phenomenon without reference to the ultimate cause of anything." Causation, Mill said, is simply uniform antecedence.

But even after we have become clear that Science has not to do with a First Cause, or with Final Causes, great ambiguities remain. As Prof. Bergson points out, even in scientific

discourse three different meanings of the term "cause" are frequently confused. "A cause may act by impelling, by releasing, or by unwinding. The billiard-ball, that strikes another, determines its movement by *impelling*. The spark that explodes the powder acts by *releasing*. The gradual relaxing of the spring that makes the phonograph turn, *unwinds* the melody inscribed on the cylinder: if the melody which is played be the effect, and the relaxing of the spring the cause, we must say that the cause acts by *unwinding*.

"What distinguishes these three cases from each other is the greater or less solidarity between the cause and the effect. In the first, the quantity and quality of the effect vary with the quantity and quality of the cause. In the second, neither quality nor quantity of the effect varies with quality and quantity of the cause: the effect is invariable. In the third, the quantity of the effect depends on the quantity of the cause, but the cause does not influence the quality of the effect: the longer the cylinder turns by the action of the spring, the more of the melody I shall hear, but the nature of the melody, or of the part heard, does not depend on the action of the spring.

"Only in the first case, really, does cause *explain* effect; in the others the effect is more or

less given in advance, and the antecedent invoked is—in different degrees, of course—its occasion rather than its cause."

In the first case, where the cause acts by impulsion, what is in the effect was already in the cause; the momentum of the one billiard-ball passes in great part into the other; the causal explanation is complete.

In the second case, where the cause acts by releasing, it is an indispensable condition; it pulls the trigger apart from which the effect will not occur. But it does not explain the effect. The egg of a sea-urchin will develop without being fertilized if it be immersed for a short time in sea-water to which some magnesium chloride or the like has been added, and there are many other ways of inducing "artificial parthenogenesis." But the cause in this case in only a trigger-puller.

In the third case, there is more than trigger-pulling, but the cause does not explain more than the rate or duration of the effect.

People are wont to recognize themselves as the "causes" of this or that result, congratulating themselves on being the "happy cause of success," blaming themselves as being the "unfortunate cause of disaster," and this idea of an active agent effecting a change in something passive often influences the popular conception of causality.

Science seeks to free itself from this anthropomorphism.

It is part of the business of Science to account for the occurrence of events, and it does so by disclosing their "efficient causes." This simply means that the event in question is shown to be determined by preceding events; one particular set of circumstances giving rise to another.

Let us here seek the aid of a scientific philosopher, Prof. A. E. Taylor. "The notion of causation as a transaction between two things is replaced in the experimental sciences by the conception of it as merely the determination of an event by antecedent events. Similarly, with the disappearance of things as the vehicles of causal processes falls the whole distinction between an active and a passive factor. As it becomes more and more apparent that the antecedent events which condition an occurrence are a complex plurality and include states of what is popularly called the thing acted upon as well as processes in the so-called agent, science substitutes for the distinction between agent and patient the concept of a system of reciprocally dependent interacting factors. These two substitutions give us the current scientific conception of a cause as the totality of the conditions' in the presence of which an event occurs, and in the absence of any member of which it does not occur.

More briefly, causation in the current scientific sense means sequence under definitely known conditions."

This view of cause and effect as earlier and later stages of the same continuous process, unified by a pervading principle, brings us back to the "descriptive" ideal of scientific explanation. "According to this doctrine, advocated by such eminent thinkers as Kirchhoff, Mach, and Ostwald among physicists, and, with various modifications, Avenarius, Münsterberg, Royce, and James Ward among recent philosophers, the ultimate ideal of science, or at any rate of physical science, is simply the description of the course of events by the aid of the fewest and simplest general formulæ. *Why* things happen as they do, it is now said, is no proper question for science; its sole business is to enable us to calculate *how* they happen."

Reduction to Simpler Terms.—It is the continual aim of science to reduce the number of categories or necessary concepts. This is the art of wielding William of Occam's razor—"Entia non sunt multiplicanda præter necessitatem." "Entities are not to be multiplied beyond necessity." Of the effort to reduce the categories let us take a famous illustration. On the occasion of his jubilee (1896) as Professor of Natural Philosophy, Lord Kelvin, then a veteran

of seventy-two, surprised many by a remarkable utterance: "One word characterizes the most strenuous of the efforts for the advancement of science that I have made perseveringly during fifty-five years; that word is failure. I know no more of electric and magnetic force, or of the relation between ether, electricity, and ponderable matter than I knew and tried to teach my students of natural philosophy fifty years ago in my first session as Professor."

It is instructive to inquire—from the experts, of course—what this indefatigable genius, whose life was a sequence of brilliant successes, meant by speaking of failure. Prof. Silvanus P. Thompson in his *Life of Lord Kelvin* explains the case. "The trend of modern ultra-physics with respect to the constitution of matter is towards the following five categories: (1) the *ether*, that is, the *plenum* filling space; (2) the *electron*, conceived as a plexus in the ether, probably of two species; (3) the *atom*, a complex of electrons in the ether; (4) the *molecule*, a specific group of atoms (or in some cases one atom); (5) the *mass*, an assemblage of molecules. Energy is involved in the construction of any of these out of any other.

"Lord Kelvin's effort seems to have been to find a theory to reduce the necessary concepts to the smallest number—matter and energy, or, by means of the vortex theory, to ether and energy.

In the end he found it necessary to bring in electricity as well. But who shall call this failure?" We understand, however, why Kelvin himself, actuated by the desire to reduce all physical phenomena within the duality of matter and energy—an ideally scientific desire—should confess in this respect to failure.

In connection with the reduction of natural processes to simpler terms, we must be careful not to allow the idea to become tyrannical. It is not always possible to effect a reduction, and it is not always relevant. Moreover, it is not always easy to make sure that the reduction is complete; some residual phenomena may escape which are at the very heart of the matter.

We cannot describe thinking in physiological terms, still less in physical terms. By psychological analysis we may perhaps make it more intelligible, but not otherwise. That is to say, we cannot bring it under any general biological or physical concept. And although we are sure that a thinking man developed in time out of a fertilized egg-cell, we cannot reduce the activities of the thinking man to what we know of the activities of the cell. And, again, as we shall explain more fully in the section on "particular aims," even if a physico-chemical reduction were effected of all that goes on in the cell, that would not give us a useful biological account of its behaviour,

e. g. of its development. For that requires a historical explanation.

Laws of Nature.—If Science is only description, what is to be said of the Laws of Nature, which Science has discovered, which, moreover, things used to "obey," when we were at school? Let us find an answer to this question in the words of a keen investigator, who, having helped to make physical laws, should know something about them. "We must confess," says Prof. J. H. Poynting, "that physical laws have greatly fallen off in dignity. No long time ago they were quite commonly described as the Fixed Laws of Nature, and were supposed sufficient in themselves to govern the universe. Now we can only assign to them the humble rank of mere descriptions, often erroneous, of similarities which we believe we have observed" (Address, British Association, 1889, p. 616).

Prof. Poynting goes on to say that a "law of nature explains nothing—it has no governing power, it is but a descriptive formula which the careless have sometimes personified. There may be psychological and social generalizations which really tell us *why* this or that occurs, but chemical and physical generalizations are wholly concerned with the *how*."

In other words, concurrently with the change in our conception of physical law has come a

change in our conception of physical explanation. The change is in our recognizing that "we explain an event not when we know 'why' it happened, but when we know 'how' it is like something else happening elsewhere or otherwise—when, in fact, we can include it as a case described by some law already set forth. In explanation we do not account *for* the event, but we improve our account of it by likening it to what we already know."

It is a common problem of science to account for a given state of things,—the appearance of an island, a cold summer, a succession of fine sunsets, a shower of gossamer, a butterfly coming out of a cocoon, and so on. In what way does science account for these things? By a description of the conditions of their coming about, and in proportion to the completeness and generality of that description is our satisfaction with the account that is given. We are particularly well satisfied when what seemed to be an exception is shown to prove the rule—that is to say, when an apparently strange event is shown to conform to an established law.

Let us take a concrete case given by Prof. Karl Pearson (*Grammar of Science*, ed. 1900, p. 99). "The law of gravitation is a brief description of *how* every particle of matter in the universe is altering its motion with reference to every other particle. It does not tell us *why* particles

thus move; it does not tell us *why* the earth describes a certain curve round the sun. It simply resumes, in a few brief words, the relationships observed between a vast range of phenomena. It economizes thought by stating in conceptual shorthand that routine of our perceptions which forms for us the universe of gravitating matter."

To the same purpose, in his impressive *History of European Thought in the Nineteenth Century*, Dr. J. T. Merz writes: "A complete and simple description—admitting of calculation—is the aim of all exact science. . . . We shall not expect to find the ultimate and final causes, and science will not teach us to understand nature and life. . . . Science means 'the analysis of phenomena as to their appearance in space and their sequence in time.'" Or again, the true nature of scientific explanation is suggested by Kirchhoff's definition of mechanics, as the science of motion, whose object it is "to describe completely and in the simplest manner the motions that occur in nature."

Huxley expressed the same general view of the Laws of Nature in a letter to Kingsley in 1863:—

"This universe is, I conceive, like to a great game being played out, and we poor mortals are allowed to take a hand. By great good fortune the wiser among us have made out some few of the rules of the game, as at present played.

We call them 'Laws of Nature,' and honour them because we find that if we obey them we win something for our pains. The cards are our theories and hypotheses, the tricks our experimental verifications."

Particular Aims of Different Sciences.—It was Kant who said that any branch of knowledge contains just so much *science* as it contains of mathematics; and this is not very different from saying that all science begins with measurement. If this view is pressed it leads to the conclusion that the only perfect science is mechanics, and that the only quite precise sciences are those dealing with processes which can be analysed into the motions of ideal corpuscles.

This seems to us an impracticable ideal of precision, for it must be noted that facts whose mechanical analysis is not within sight need not on that account be treated unscientifically. They may be measured, though not with the same measure as is used for the stars in their courses. Complex as are the inborn variations of plants and animals, they can be treated by the same statistical methods as are used in recording the simple phenomena observed when dice are thrown ten thousand times. Mysterious as are the facts of inheritance, the expert can occasionally prophesy safely as to the nature of the chicks which will emerge from an unhatched

setting of eggs. There is a great deal of precise measurement in physiology and psychology which has led or is leading to exact science, though not to mechanical re-description.

Moreover, to return to a consideration referred to in the section on reduction, we are very strongly of opinion that Biology does not necessarily make progress towards perfection by the mechanical analysis of changes that go on in living bodies. That kind of analysis or reduction to the lowest terms is an engine of research which must be worked for all it is worth, but it does not directly answer any biological questions. For Biology has a particular end—that of describing the life of plants and animals, and that end is not necessarily achieved by discoveries in the physics and chemistry of living bodies. We watch a bird building its nest. We know that there is an intricate sequence of physical and chemical changes going on in its body. We feel sure that nothing occurs that contradicts any of the established laws of chemistry and physics. We do not know whether a complete chemical and physical description of what occurs is realizable or not. We know that it has not been given. But we feel sure that if it were given it would not directly help us to understand the bird building its nest. For that requires a different kind of description—with different concepts, which

recognize the bird as an historic being with a mind of its own.

Comte maintained very strongly that mechanical principles broke down *as inapplicable* beyond the physical order, but that is not quite the point. They *are* applicable in Biology; they have been of great service as a means of investigation in Biology; their application has brought the characteristically vital into bolder relief. But the point is that they are not exhaustive of what occurs, and that they do not give us distinctively biological descriptions.

It must be clearly understood that Biology has an aim far wider than that of giving an account of the physical and chemical processes that go on in the living body. It has to tell the story of individual development, the story of racial evolution, and the story of the everyday behaviour of the organism. It has to recognize the past living on in the present, the individuality and spontaneity of the creature, and, often at least, a dramatic element in life—much, in fact, that requires a kind of description very different from that of Chemistry and Physics. In the same way it might be shown that Psychology has a particular aim of its own, which is distinct from that of Biology.

More generally stated, the important idea which we wish to make clear is that what defines

a science is not its subject-matter, but its point of view,—the particular kind of question it asks. The lark singing at heaven's gate is a fact of experience which may be studied physically, biologically, and psychologically, but a complete answer to the questions asked by Physics would not answer those asked by Biology, still less those asked by Psychology.

The Evolutionary Aim.—The end of Science is not reached in the formulation of things as they are, it has also an historical or evolutionary aim. In every department of knowledge the question we are continually asking is—"How have these things come to be?" The solar system is traced back to a vast nebula.

> "The solid earth on which we tread
> In tracts of fluent heat began."

There are hints of inorganic evolution, one kind of matter giving rise to another, as Uranium to Radium. There is a history if not a sermon in every stone. And when we come to organisms we find evolution in the stricter sense, race giving rise to race by processes of slow transformation still very imperfectly understood. The conception extends to language and literature, to art and institutions, to everything. It is in this genetic view of Nature and of Man that Science completes itself, and joins hands with Philosophy.

SUMMARY.—*The aim of Science is to describe the impersonal facts of experience in verifiable terms as exactly as possible, as simply as possible, and as completely as possible. It is an intellectual construction,—a working thought-model of the world. In its "universe of discourse" it keeps always to experiential terms, or verifiable derivatives of these. It is as far on one side of common-sense as poetry is on the other. It deals with "facts" which have no dependence on man's will, which must be communicable and verifiable. It is descriptive formulation, not interpretative explanation. The causes that Science seeks after are secondary causes, not ultimate causes; effective causes, not final causes. Indeed, its causes and effects are simply earlier and later stages of the same continuous process. Science always seeks to reduce things to a common denominator and to reduce the number of categories or necessary concepts. The "Laws of Nature" are descriptive formulæ in "conceptual shorthand" of the routine of our perceptions. Each science has its distinctive questions and concepts of its own. The end of Science is not reached in the formulation of things as they are, it has also to describe how they have come to be.*

CHAPTER III

SCIENTIFIC METHOD

"Induction for deduction, with a view to construction."—COMTE.

The Logic of Science—The Keen Eye—Collecting Data—Measurement—Arrangement of Data—Analysis and Reduction—Hypothesis—Test Experiments and Control Experiments—Formulation—The Scientific Use of the Imagination—The Fundamental Postulate of Science—Summary.

SCIENCE is not wrapped up with any particular body of facts; it is characterized as an intellectual attitude. It is not tied down to any peculiar methods of inquiry; it is simply sincere critical thought, which admits conclusions only when these are based on evidence. We may get a good lesson in scientific method from a business man meeting some new practical problem, from a lawyer sifting evidence, or from a statesman framing a constructive bill.

How, then, does science differ from ordinary knowledge? It is criticised, systematized, and generalized knowledge. That is to say, the student of science takes more pains than the man

in the street does to get at the facts; he is not content with sporadic knowledge, but will have as large a body of facts as he can get; he systematizes these data and his inferences from them, and sums up in a generalization or formula. In all this he observes certain logical processes, certain orders of inference, and we call this *scientific method.*

The Logic of Science.—Of modes of inference there are no more than there were in the days of Aristotle, who recognized three: (*a*) from particular to particular (analogical reasoning), (*b*) from particulars to general (inductive reasoning), (*c*) from general to particular (deductive reasoning). Let us take a few examples.

(*a*) *Analogical Reasoning.*—The geologist tells us the story of the making of the earth and describes what happened millions of years ago, and in many cases he relies on analogical reasoning. From the consequences of particular happenings to-day he infers the efficient causes of events that happened in the Devonian age. He sheds the light of the present on the dark abysses of the past.

When Darwin argued from the particular variations which he observed in his domesticated pigeons and cultivated plants to variations which might have occurred in unthinkably distant æons, he was trusting to analogical reasoning. Often

it is the only alternative, but it should be used with restraint in arguing from the present to remote antiquity, for it is obvious that some important difference between the conditions then and those of to-day may invalidate the argument.

(*b*) *Inductive Reasoning.*—This is argument from particulars to the universal, and science is full of illustrations. "Galileo had smooth inclined planes made; and then, by rolling balls down them and measuring the times and squares of descent, he discovered inductively that the space fallen is always as the square of the time of falling; so that, if a body in one second of time falls about sixteen feet, in two seconds it will have fallen sixty-four feet, four times as far (time 2-squared), in three seconds one hundred and forty-four feet, nine times as far (time 3-squared)."

The inductive method may almost be called Baconian, for Bacon was the first to show that the sound way of studying Nature was to work up from particulars to principles. He called his method the new instrument—the Novum Organum. It was founded on the principle that things which are always present, absent, or varying together, are casually connected.

(*c*) *Deductive Reasoning.*—This is argument from the universal to particulars, the kind of inference which enables the long arm of science to reach back through the ages that are past and

forward into those which are to come. By deduction Neptune was discovered before it was seen. By deduction, given three good observations of a passing comet, we can predict its return to a night.

As a good example, cited by Prof. Case, of the abuse of the deductive method by one of the greatest of all intellects, we may recall an argument used by Aristotle to support the old circular astronomy. The stars are eternal and must have eternal motion. The only eternal motion is circular. Therefore the stars move in circles round the earth. "It is a case of two hypothetical premises leading to a false conclusion. Every step is false. There is nothing for it but experience. The real question is how the stars move in point of fact."

It is not within the scope of this little book to enter into a detailed discussion of the various scientific methods—such as the mathematical, the empirical, the explanatory, and the verificatory, which Mill distinguished. But there are two important considerations to be borne in mind, —first, that great conclusions seem often to be reached by a flash of imaginative genius, perhaps the expression of long-continued processes of subconscious cerebration; and, second, that in actual practice induction and deduction are mingled in intricate ways.

In many instances we find that experiment and

induction have afforded a basis from which deduction has reached far beyond experience. The supreme illustration of the power of combined methods is to be found in Newton's *Principia*, for here, as Prof. Case has shown in detail, the method is neither the deductive Aristotelian, nor the inductive Baconian, but both; it is the interaction of induction and deduction in a mixed method. "The full title, *Philosophiæ Naturalis Principia Mathematica*, implies a combination of induction and deduction. It is also a combination of analysis and synthesis: it proceeds from facts to causes as well as from causes to facts."

The Keen Eye.—We use this phrase, metaphorically as well as literally, to describe what may be called a preliminary condition of all scientific investigation—one certainly that has led to many discoveries. We mean the observant habit, the alert mind, the appetized intelligence, the inquisitive spirit, which notices whatever is unusual, which sees a problem in the most commonplace occurrences. It is difficult to define this quality, which is at its highest when sensory alertness is combined with a habit of wondering and pondering.

Of Clerk Maxwell, who "enriched the inheritance left by Newton and consolidated the work of Faraday," it is said that his first recollection was that of lying on the grass before his father's

house, and looking at the sun, and *wondering*. It was said of Edward Forbes, one of the most brilliant of British naturalists, that "he had a hawk's eye to see in a moment any plant that was new." And it is our impression, based on the history of science, that—apart from genius—most discoveries have been psychologically due to a combination of the keen eye with the inquisitive spirit. Let us recall what Tyndall has told us of the way in which Robert Mayer was led to his theory of energy.

"In the summer of 1840, as he himself informs us, he was at Java, and there observed that the venous brood of some of his patients had a singularly bright red colour. The observation riveted his attention; he reasoned upon it, and came to the conclusion that the brightness of the colour was due to the fact that a less amount of oxidation sufficed to keep up the temperature of the body in a hot climate than in a cold one. The darkness of the venous blood he regarded as the visible sign of the energy of oxidation" (Tyndall, 1876, p. 274).

He was drawn to the whole question of animal heat, to the relation between heat generated and work done, and to his remarkable contributions to the mechanical theory of heat in particular, and to the theory of energy in general. All roads lead to Rome, and he must be a bold man who

will declare any of Nature's beckonings to be unworthy of attention.

Collecting Data.—The first step in beginning the scientific study of a problem is to collect the data, which are or ought to be "facts." And by this we mean, in Prof. Taylor's words, "experiences which we cannot altogether fashion as we please to suit our own convenience, or our own sense of what is fitting or desirable, but have largely to accept as they come to us." As is often said, "Facts are chiels that winna' ding"—that is to say, they cannot be coerced or denied, and they are verifiable by all who have equal opportunities and equipment for experiencing them.

In the so-called "natural sciences" this collection of data implies observation, and much depends on the degree of excellence which the observer attains. The fundamental virtues are clearness, precision, impartiality, and caution. Common vices are rough and ready records, reliance on vague impressions, acceptance of second-hand evidence, and picking the facts that suit. Since observers are fallible mortals, we readily understand the importance of co-operation, of independent observations on the same subject, of instrumental means of increasing the range and delicacy of our senses, and of automatic impersonal methods of registration such as photography supplies.

Measurement.—In collecting data for scientific thinking the fundamental virtue is accuracy, and it is impossible to exaggerate its importance. Science begins with measurement, with which we include, of course, every method of precise registration.

Many advances, Lord Kelvin said, have owed their origin to protracted drudgery. "Accurate and minute measurement seems to the non-scientific imagination a less lofty and dignified work than looking for something new. But nearly all the grandest discoveries of science have been but the rewards of accurate measurement and patient, long-continued labour in the minute sifting of numerical results." In illustration he instanced the discovery of the law of gravitation by Newton, Faraday's theory of specific inductive capacity, Joule's law of thermo-dynamics, and that of the continuity of the gaseous and liquid states by Andrews.

One of the most instructive recent illustrations of the value of attending to little hints is to be found in the story of the discovery of argon. Lord Rayleigh made a number of precise weighings of the oxygen contained in a carefully weighed and measured glass flask at 15° C. and 760 mm. There were very minute differences in the weights recorded,—affecting the fourth decimal place. He then made a series of weighings of pure nitrogen

in the same vessel, and took note of the minute differences in the weights recorded. Especially were there differences in the weighings of nitrogen made from certain of its compounds and nitrogen obtained by removing oxygen, water, traces of carbonic acid and other impurities from atmospheric air. As the differences between the weighings seemed greater than the possibilities of error, the possibility suggested itself that the nitrogen derived from the air might not be quite pure.

Now in 1785 Cavendish, in his analysis of air, had also tried whether the removal of nearly twenty-one volumes of oxygen and a small quantity of carbonic acid from one hundred volumes of atmospheric air left pure nitrogen. His testing left a residual bubble of something. It might, Cavendish thought, have been introduced accidentally during the manipulations, but he also suggested that it might be a gas neither nitrogen nor oxygen, and, if so, that there was about one volume of it to every hundred of atmospheric nitrogen. For more than a century the question rested.

But in 1894 Lord Rayleigh and Sir William Ramsay, in considering the discrepancies in the weighings of atmospheric nitrogen, remembered Cavendish's residual bubble, and Sir William Ramsay speedily discovered that it consisted of argon (about one and a half times as heavy as

nitrogen) and some other elementary gases. The discovery was the reward of precision and a signal instance of the value of attending to even minute discrepancies.

It is doubtless a pity when circumstances lead a man of science to spend his whole life in collecting data and in measurement, but it is ungenerous and unwise to speak of this in a superior way as "hodman's work." Let us take an illustration from the volume of Astronomy by Mr. Hinks—the somewhat monotonous and quantitative work of star-cataloguing, which Hipparchus is supposed to have begun more than a century before Christ, which is continued even unto this day. What is the use of it? The author points out (1) that it forms an essential basis for the applications of astronomy—the determination of time, navigation, surveying; (2) that without good star places we can have no theory of the motions in the solar system; and (3) that "without accurate catalogues of the stars we can know nothing of the grander problems of the universe, the motion of our sun among the stars, or of the stars among themselves."

In addition to its necessity in furnishing materials for Science, there is great educational value in the discipline of making definite and accurate measurements. Speaking of its utility, *even* for those students who were destined for the

Church, Lord Kelvin said in an address at Bangor: "There is one thing I feel strongly in respect to investigation in physical or chemical laboratories —it leaves no room for shady, doubtful distinctions between truth, half-truth, whole falsehood. In the laboratory everything tested or tried is found either true or not true. Every result is *true*. Nothing not proved true is a *result;* there is no such thing as doubtfulness." It is very interesting that Clerk Maxwell should speak in one sentence of "those aspirations after accuracy in measurement, and justice in action, which we reckon among our noblest attributes as men."

Arrangement of Data.—In many cases the accumulation of data has to be followed by not less laborious arrangement. The facts have to be classified, and that from different points of view, and without prejudice. The object of this is to discover correlations and uniformities of sequence. In dealing with an enormous mass of facts in regard to the Migration of Birds, one of the leading inquirers into this fascinating subject, Mr. Eagle Clarke, of the Royal Scottish Museum, required more time for the orderly classification of the data than was required for their collection.

Just as observation is made incalculably more effective by the use of instruments, so in classifying and registering facts, the use of statistical

devices—curves and the like—is invaluable, as is well illustrated in their successful application to the difficult problems of biometries, notably of variation and heredity.

Bad observation may invalidate the whole scientific process, but carelessness in the arrangement of data may be equally fatal. It has often happened that attending to some minute discrepancy revealed in the classification of data has led to the elucidation of the whole problem. Thus it has become a maxim that no apparent departure from the rule should be treated as trivial. It may mean an error of observation; it has often led, *e. g.* in Chemistry and Astronomy, to an important clue.

Analysis and Reduction.—In many scientific inquiries it is necessary to pass below the everyday facts of experience to those that underlie them. There is a process of analysis or reduction to simpler terms. In order to understand the first facts better we try to resolve them into others, which can be described in simpler or more generalized terms. There are all sorts of analyses and reductions—dissecting an animal, cutting microscopic sections of a rock, making a chemical analysis of a substance—and their utilization is indispensable.

Hypothesis.—We mean by a scientific hypothesis a provisional formulation, a tentative solu-

tion, and it is part of the scientific method to make them and test them. While there seems to be no doubt that some scientific conclusions have arisen in the mind of the investigator as if by a flash of insight, in the majority of cases the process of discovery is a slower one. The scientific imagination devises a possible solution —an hypothesis—and the investigator proceeds to test it. He makes intellectual keys and then tries whether they fit the lock. If the hypothesis does not fit, it is rejected and another is made. The scientific workshop is full of discarded keys.

It need hardly be said that whether the hypothesis is reached imaginatively or laboriously, whether it is suggested by induction from many particulars or as a deduction from some previously established conclusion, it has to be tried and tested until it rises to the rank of a theory.

Test Experiments and Control Experiments.—The distinction between observation and experiment is not of much importance. In the former we study the natural course of events; in the latter we arrange artificially for certain things to occur. The method of experiment saves time and we can make surer of the conditions. In studying the effect of electric discharges on living plants, it would be worse than tedious to wait for the lightning to strike trees in our vicinity, so we mimic the natural phenomena in

the laboratory. In studying phenomena like hybridization, we are obviously on much surer ground with experiment than with observation in natural conditions.

Alterations in the conditions of occurrence which it might be difficult or impossible to arrange in Nature can be readily effected in the laboratory. It is thus possible to discover which of the antecedents are causally important. Cattle begin to die of some mysterious epidemic disease; bacteria are found to be abundant in the dead bodies; it is conjectured that the disease is bacterial. Some of the bacteria are peculiar, and it is observed that they occur in all the victims. The hypothesis is made that this particular species of bacterium is responsible for the disease. But since the epoch-making experiments of Koch which showed that *Bacillus anthracis* is the cause of anthrax (splenic fever, or wool-sorter's disease in man), no one dreams of stopping short of the experimental test. The suspected bacillus is isolated, a pure culture is made, this is injected into a healthy animal, and if the disease ensues the proof is complete.

Besides furnishing fresh data, an experiment may be of use at a later stage in scientific procedure, namely, in putting the hypothesis to the proof; and much of the success of a scientific worker often depends on his ingenuity in think-

ing out these crucial or test experiments. Let us notice two or three examples.

When bacteriology was still in its infancy, and Pasteur was still fighting for his discovery that putrefaction was due to the life of micro-organisms in the rotting substance, he put his theory to a crucial test which is continually repeated now-a-days as a class experiment or for practical purposes in the preservation of various foods. He took some readily putrescible substances, sterilized them by boiling, and hermetically sealed the vessel. No putrefaction occurred.

When Von Siebold and his fellow-workers had convinced themselves indirectly that certain bladderworms, *e. g.* those which occur in the pig and the ox, were the young stages of certain tapeworms which occur in man, they made the crucial and almost heroic experiment of swallowing the bladderworms. By becoming soon afterwards infected with the tapeworms they proved the truth of their theory.

Or let us take a simple case where the method of exclusion is combined with a control experiment. The freshwater crayfish has a sense of smell, as is proved by the rapid way in which it retreats from strong odours. Investigation led to the hypothesis that this sense was located in the antennules or smaller feelers. This was verified by observing that a crayfish bereft of

these appendages did not react to a strong odour, whereas—here the control experiment comes in —in exactly the same conditions and to the same stimulus another crayfish with its antennules intact did actively respond. Pursuing precisely the same two methods, the investigator proved that the seat of smell was in peculiarly shaped bristles on the outer fork of the antennules.

A great experimental philosopher is reported to have said: "Show me the scientific man who never made a mistake, and I will show you one who never made a discovery." This was in allusion to the everyday method of "trial and error," which is part of the logic of experimenting. Different hypotheses are tried till the one that fits the facts is found.

It is interesting to notice that a scientific conclusion may sometimes be safely accepted before its demonstration is visibly complete, a famous instance being Harvey's demonstration of the circulation of the blood (1628). From the structure of the heart, the observed flow in different parts of the system, and the valves in the veins, he almost completely demonstrated the circulation. Only one step was awanting. "Harvey's difficulty lay in the circumstance that as the microscope was not in use, no known path existed by which the blood could be conveyed from the smallest arteries into the smallest veins; there was

a gap in the vascular series, but his demonstration made it a logical certainty that a bridge across this gap was in existence" (Gotch, 1906, p. 47). Although it was not till 1661 that Malpighi saw the blood flowing through transparent capillaries from the smallest arteries to the smallest veins, Harvey's demonstration might have passed at once into physiological science (which was far from being its reception) for the simple reason that it was an observed fact that the blood goes on ceaselessly flowing throughout life. *The system works*, therefore the unseen bridge across the gap must be there.

FORMULATION.—The final step in scientific method is to sum up what has been proved in terms as clear and terse as possible. A theory is stated, a formula is invented, or, more frequently a new set of facts is brought into subjection to an old law. The theory must fit the facts; it must be a complete and consistent description; its terms must be either directly experimental, or accessible to experimental tests; and it must be impersonal to this extent, that it will appear valid to all who can appreciate the evidence.

"The final touchstone," Prof. Karl Pearson says, "is equal validity for all normally constituted minds." Moreover, the theory must be compared with already established conclusions. If there is any discrepancy between the new and

old, some reconsideration of the one or the other, or of both, will be necessary.

Lord Kelvin was wont to emphasize the distinction between two stages of progress in science, the "Natural History" stage and the "Natural Philosophy" stage. In his introductory lecture (1846) as Professor of Natural Philosophy in Glasgow University—a lecture which he repeated for over fifty years—he said: "In the progressive study of natural phenomena, that is, the phenomena of the external world, the first work is to observe and classify facts; the process of inductive generalization follows, in which the laws of nature are the objects of research. These two stages of science are designated by the expressions of *natural history* and *natural philosophy*." In other words, there is an observational and descriptive stage, followed by generalization and formulation.

It is necessary, then, to make a clear distinction between the raw materials of science and the systematizations which raise these to a higher power. As Prof. P. G. Tait once said: "Descriptive botany, natural history, volumes of astronomical observations, etc., are collections of statements, often facts, from which scientific truth may ultimately be extracted, but they are not science. Science begins to dawn, but only to dawn, when a Copernicus, and after

him a Kepler or a Galilei, sets to work on these raw materials, and sifts from them their essence. She bursts into full daylight only when a Newton extracts the quintessence. There has been, as yet, but one Newton; there have not been very many Keplers."

THE SCIENTIFIC USE OF THE IMAGINATION.—This was the title of a famous lecture in which Tyndall discussed with eloquence and insight the function of imagination in scientific research. "Bounded and conditioned by co-operant reason," he said, "imagination becomes the mightiest instrument of the physical discoverer." "There is in the human intellect a power of expansion, I might almost call it a power of creation, which is brought into play by simple brooding over facts, 'the spirit brooding over chaos.'"

It may be that the imaginative brooding suggests a solution in some way that we do not at present understand—life is essentially creative; it may be that there is a more or less unconscious cerebral experimenting; it is certain that letting the mind play among facts has often led to magnificent conclusions. It seems that the solution is often reached first and the proof supplied afterwards. Newton spoke of reaching his discoveries "by attending my mind thereunto," but it would be extremely interesting to know more precisely what he meant. The steps by

which he reached his gravitation-formula illustrate an interlacing of induction and deduction, but we must agree with Prof. Gotch that the law was "the conception of a creative mind gifted with imagination." "In the language of Tyndall, this 'passage from a falling apple to a falling moon' was a stupendous leap of the imagination, for his enunciated law applies in conception to the universe, thus extending into boundless space and persisting through endless time."

At the beginning of this chapter we hinted that all methods are transcended by men of genius, whose magnificent operations the history of Science discloses. We cannot give a psychological account of the way in which the greatest of them made their discoveries. Their methods were secondary. "God said, Let Newton be! and there was light." Of Kelvin, his biographer says:—

"Like Faraday, and the other great masters in science, he was accustomed to let his thoughts become so filled with the facts on which his attention was concentrated that the relations subsisting between the various phenomena dawned upon him, and he *saw* them as if by some process of instinctive vision denied to others. It is the gift of the seer. . . ." "His imagination was vivid; in his intense enthusiasm he seemed to be driven, rather than to drive himself. The man was lost

in his subject, becoming as truly inspired as is the artist in the act of creation."

What a famous mathematical teacher, Hopkins, "who had had, perhaps, more experience of mathematical minds than any man of his time," said of Clerk Maxwell, may also serve to illustrate our point in regard to genius. His striking words were: "It is not possible for that man to think incorrectly on physical subjects."

In short, it must be admitted that genius transcends methods. As Prof. Silvanus P. Thompson says in his *Life of Lord Kelvin*:—

"Observation, experience, analysis, abstraction, imagination, all these are necessary—but are they all? Something seems yet wanting to account for what we call the intuition of the master-mind. It is surely more akin to the innate faculty of the great artist than to the trained powers of the analyst or the logician."

THE FUNDAMENTAL POSTULATE OF SCIENCE.—There is one fundamental postulate underlying scientific procedure,—a postulate which is verified with every fresh step. It is the postulate of the Uniformity of Nature. This, which may be analysed into a number of postulates, means that for our human purposes there is stability in the properties of things, that the same situations are continually recurring, that there is a routine in the order of Nature—a routine without gaps or

interpolations, in which every event is determined by antecedent events.

Clerk Maxwell discussed the Uniformity of Nature in his famous *Discourse on Molecules* (1873).

"In the heavens we discover by their light, and by their light alone, stars so distant from each other that no material thing can ever have passed from one to another; and yet this light, which is to us the sole evidence of the existence of these distant worlds, tells us also that each of them is built up of molecules of the same kinds as those which we find on earth. A molecule of hydrogen, for example, whether in Sirius or in Arcturus, executes its vibrations in precisely the same time.

"Natural causes, as we know, are at work which tend to modify, if they do not at length destroy, all the arrangements and dimensions of the earth and the whole solar system. But though in the course of ages catastrophes have occurred and may yet occur in the heavens, though ancient systems may be dissolved and new systems evolved out of their ruins, the molecules out of which these systems are built—the foundation-stones of the material universe—remain unbroken and unworn. They continue this day as they were created—perfect in number and measure and weight. . . ."

In the more exact sciences—such as astronomy—the verification of the uniformity is complete, since the routine of sequences can be summed up in rigid mechanical formulæ. We cannot do this in Biology, yet here also we make and verify the postulate of the Uniformity of Nature. In spite of a strong personal element in many living creatures which makes their behaviour in complicated situations unpredictable, there are uniformities both of action and reaction. Without these, indeed, there could not be a science of Biology at all, but with these there is a basis for calculation, prediction, and action, which is reliable, though not to the same degree as that afforded by the more exact sciences.

Summary.—*The logic of scientific discovery is chiefly an intricate interlacing of induction and deduction. While genius has counted for much in the history of science, many great discoveries have been the harvest of a keen eye and an inquisitive spirit. The first step in scientific procedure is to collect data, and all science begins with measurement. The second step is the arrangement and classification of facts. Auxiliary to this and to formulation is the process of analysis or reduction to simpler terms. In order to fulfil the aim of describing facts of experience as exactly as possible, as simply as possible, as completely as possible, it is often necessary to try one hypothesis after*

another. An important step in procedure is the carrying out of test experiments. The final result is a general formula or a law of Nature, or, more frequently, the inclusion of a new set of facts within an old law. At every step imagination counts and its highest flights are called genius. The fundamental postulate of science is the Uniformity of Nature.

CHAPTER IV

CLASSIFICATION OF THE SCIENCES

"The divisions of the sciences are not like different lines that meet in one angle, but rather like the branches of trees that join in one trunk."—Bacon.

The Convenience and the Difficulties of Classification—Bacon's Classification—Comte's Classification—Spencer's Classification—Bain's Classification—Karl Pearson's Classification—Bio-physics—Exact Science—The Classification Adopted—The Interest of the Classification of the Sciences—The Correlation of the Sciences—Summary.

The Convenience and the Difficulties of Classification.—Science takes the whole known universe for its province, and every communicable verifiable fact of experience is included among its data. This is such a large order that it is obviously convenient to have some classification. Moreover, although there is nothing but mis-education to hinder an intelligent citizen from having a scientific interest in many different orders of facts, tastes differ, and an intellectual division of labour naturally arises. As a matter of fact, the long discipline which every science

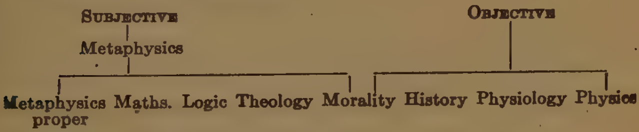
requires renders it impossible for any ordinary man to succeed in gaining a masterly familiarity with more than one department of knowledge.

The classification of the sciences is a matter of practical and intellectual convenience, but it is full of difficulties and raises very deep questions. If it be made too detailed, there is the risk of losing sight of the unity of knowledge; if it be made too general, there is the risk of denying to particular sciences that autonomy which the distinctive character of their subject-matter warrants. A compromise has to be made between two desirabilities. It is plain, for instance, that Botany and Zoology need not be separated with great insistence; they may be united without serious fallacy under the title Biology. On the other hand, there are good reasons for saying that it is a fallacy of the gravest sort to include Biology as a special section of Physics and Chemistry.

There are similar difficulties in teaching and learning. Too great specialization leads to pedantry; too little of it to superficiality. When our aim is to get a grip of scientific method, we are more likely to succeed by settling down to the thorough study of some one order of facts, than by indulging in an intellectual ramble through the universe. On the other hand, when we wish fresh points of view and new impulse

to the scientific imagination, we require width of knowledge and contacts between different disciplines.

There seems to be a peculiar fascination in attempting to classify the sciences, and many great intellects have puzzled over the problem. Thus we find Huxley, at the age of seventeen, writing: "I have for some time been pondering over a classification of knowledge. My scheme is to divide all knowledge in the first place into two grand divisions: (1) Objective—that for which a man is indebted to the external world; and (2) Subjective—that which he has acquired or may acquire by inward contemplation." He proposed this scheme:—



There have been dozens of classifications of the sciences, which have been dealt with in a very learned way by the late Prof. Robert Flint, but it is far from our purpose to discuss them here. We shall not do more than refer to a few which illustrate particular points.

BACON'S CLASSIFICATION.—In his "Intellectual Globe," Francis Bacon (1561–1626) recognized three big departments of human learning—

History, Poesy, and Philosophy or the Sciences. History, based on *Memory*, was divided into "Natural" and "Civil," a reminiscence of which is found in the title "Natural and Civil History" which was borne till lately by more than one Scottish Professorship. Poesy was based on the faculty of *Imagination*. Philosophy or the Sciences, based on *Reason*, included Divinity, which has to do with revelation, and Natural Philosophy, which has to do with God, Nature, and Man. The department dealing with Nature included Mathematics, Physics (Material and Secondary Causes), and Metaphysics (Form and Final Causes). It is obvious that this classification does not help us much to-day, but it is very interesting, as Prof. Karl Pearson points out, to notice the suggestion that the sciences are not like different lines that meet in one angle, but rather like branches of a tree that meet in one stem, "which stem grows for some distance entire and continuous before it divides itself into arms and boughs." There is here a suggestion at once of unity and of evolution.

Since the divisions of the sciences are "like the branches of trees that join in one trunk," "it is first necessary that we constitute a universal science as a parent to the rest, and as making a common road to the sciences before the ways separate." This "universal science" was a

"primary or summary philosophy," and included an inquiry into "transcendentals, or the adventitious conditions of beings." Bacon's scheme formed the basis of the gigantic work of the French Encyclopædists, but they might well have had a better. It was founded on a false idea of Memory, Imagination, and Reason as separate faculties, giving rise to separate departments of knowledge, and it is full of what seems to us to-day to be extraordinary confusion, such as the entire separation of History from Science, and the separation of Man from Nature.

COMTE'S CLASSIFICATION.—Auguste Comte (1798–1857) recognized six fundamental sciences: Mathematics, Astronomy, Physics, Chemistry, Biology, and Sociology; and a seventh supreme or final science of Morals. These, he said, form a linear series, indicative of the order of evolution, for a relatively simple, abstract, and independent science must, he maintained, always come before the relatively more special, complex, and dependent. There were two great ideas here, though both were exaggerated. The first is, that the sciences should contribute to the guidance of human conduct, for in morals there is the "synthetical terminus of the whole scientific construction." In other words, Science should afford the broad basis for the Art of Life. The second is, that the sciences form a hierarchy, those that deal with

the more complex orders of facts being dependent on those that deal with less complex orders of facts. It does not seem to us that the facts of life can be re-stated in the formulæ of chemistry and physics, or that the biologist holds in his hands the key to the problems of human society, but it is certain that an understanding and also a control of the organism has been greatly furthered by chemical and physical inquiries, and that the data of biology are full of suggestion to the sociologist. Comte's insistence on the inter-dependence and correlation of the sciences was sound.

The idea of a linear series, however, is fallacious if taken literally. It does not express an historical fact that Biology evolved or evolves from Chemistry and Physics; Astronomy cannot be separated off as a fundamental science from Physics and Chemistry, nor did it supply the foundations of Physics; Mathematics may be justly called the most fundamental of the sciences, but it is abstract and not in line with Physics, Chemistry, and Biology, which are descriptive. The ranking of Psychology as a department of Physiology (Biology) abandons the autonomy of that very distinctive science—quite gratuitously and fallaciously, we venture to think.

Spencer's Classification.—Herbert Spencer (1864) emphasized the distinction between the

Abstract Sciences of Logic and Mathematics, which deal with modes or methods of scientific description, and the Concrete Sciences which *are* the scientific descriptions. Thus Mathematics is obviously an abstract science, applicable to all sorts of things, but never inquiring what sort of things they are.

"The broadest natural division of the sciences is, he affirmed, that between sciences which deal with the abstract relations under which phenomena are presented to us, and those which deal with the phenomena themselves—between sciences which deal with the mere blank forms of existence, and those which deal with real existences" (Flint, 1904, p. 227). Among the latter, Spencer distinguished the *Abstract-Concrete Sciences*, such as Mechanics, Physics, and Chemistry which treat of realities in their elements, or of the real relations implicated in certain classes of facts, and the *Concrete Sciences*, Astronomy, Geology, Biology, Psychology, and Sociology, which deal with realities in their totalities, or with aggregates of phenomena.

"From the beginning," he says, "the Abstract Sciences, the Abstract-Concrete Sciences, and the Concrete Sciences have progressed together, the first solving problems which the second and third presented, and growing only by the solution of the problems; and the second similarly growing

by joining the first in solving the problems of the third. All along there has been a continuous action and reaction between the three great classes of sciences."

SPENCER'S SCHEME

Group I.	Abstract Sciences:—LOGIC AND MATHEMATICS
Group II.	Abstract-Concrete Sciences:—Mechanics, Physics, Chemistry
Group III.	Concrete Sciences:—Astronomy, Geology, Biology, Psychology, Sociology

"The three groups of Sciences may be briefly defined as laws of the *forms*, laws of the *factors*, laws of the *products*."

"The first, or Abstract group, is *instrumental* with respect to both the others; and the second, or Abstract-Concrete group, is *instrumental* with respect to the third or Concrete group."

"The second and third groups supply subject-matter to the first, and the third supplies subject-matter to the second; but none of the truths which constitute the third group are of any use as solvents of the problems presented by the second group; and none of the truths which the second group formulates can act as solvents of problems contained in the first group."

In this scheme, as Prof. Flint pointed out, "Spencer would seem to have himself constructed a series of sciences of the very kind which, in

opposition to Comte, he declared to be impossible. Comte meant no more by calling one science logically dependent on another than that the one placed first is instrumental as regards the one placed last, while the latter is not instrumental as regards the former. If there be a number of sciences dealing with fundamentally distinct phenomena, and so related that every antecedent is instrumental as regards every consequent, and no consequent is instrumental as regards any antecedent, a series of sciences is constituted which represents the logical dependence of its members. Spencer started with denying that there was any such series, but ended by implicitly showing that there was one. His own classification, taken in connection with the passage quoted, was a decisive refutation of what was extreme in his own criticism of the Comtist scheme. So far from having succeeded in overthrowing that scheme he only at the utmost succeeded in slightly modifying it.

"*There is a logical dependence of the sciences.* And why? Just because there is a natural dependence of phenomena. The quantitative relations with which mathematics deals are more general than the mechanical laws which physics brings to light; there can be no chemical combinations unconditioned by physical properties; vital functions never appear apart from chemical processes;

and there must be life before there can be consciousness. That remarkable hierarchy of phenomena is a fact which a cloud of abstract language or a covering of subtle reasoning may to some extent and for a short while conceal from our view, but which no language or reasoning can efface or even long obscure. And there being such a hierarchy of phenomena, it is scarcely conceivable that there should be no corresponding hierarchy of sciences" (Flint, 1904, p. 231).

We have quoted this strong opinion from an authority who earned a high reputation in dealing with philosophical questions, but it appears to us to require some safeguarding—in one direction in particular, to which we have already referred, and must refer yet again. There are, of course, physical and chemical processes in the living body; we may speak of the physics and chemistry of organisms; but these do not constitute biology, nor do they directly contribute to the solution of biological problems, which have primarily to do with the ways of living creatures as such.

One of the features of Spencer's classification which has been much criticized—and justly, as it seems to us—is the awkward naming and grouping of the "Abstract-Concrete" Sciences, which included Mechanics, Physics, Chemistry and Sciences of Light, Heat, Electricity, and

Magnetism. It is difficult to see why Mechanics should be called "abstract-concrete," or why the Sciences of Heat, Light, etc., are not included under Physics, and so on.

BAIN'S CLASSIFICATION.—Prof. Alexander Bain distinguished Fundamental (or Abstract) Sciences from Dependent (or Concrete) Sciences, and in so doing, apart from the nomenclature, he made a distinct step of progress. It is evident that √ Geography (one of the *dependent* sciences) is derivative, complex, and particulate, as contrasted with Physics (one of the *fundamental* sciences), which is independent, simple, and general.

The fundamental sciences, according to Bain, were Logic, Mathematics, Mechanics or Mechanical Physics, Molecular Physics, Chemistry, Biology, and Psychology. "In every one of these," he said, "there is a distinct department of phenomena; taken together they comprehend all known phenomena, and the order indicated is the order from simple to complex, and from independent to dependent, marking the order of study and evolution." Taken collectively "they contain the laws of every known process in the world, whether of matter or of mind; and set forth these laws in the order suitable for studying and comprehending them to the greatest possible advantage."

The dependent sciences include Mineralogy, √√√

Meteorology, Geography, Botany, Zoology, Philology, and Sociology—the point in the definition being that "no one of them involves any operation but what is expounded in the fundamental or departmental sciences."

Thirdly, Bain suggested a third group of Practical Sciences, but here his usual clearness of thought is less evident. For he includes within one very elastic band no only what we now call "Applied Sciences," but also some of the arts like Architecture, and several sub-sciences like Æsthetics (surely a division of Psychology), not to speak of Ethics and Economics. The idea of his third group was a good one but the contents formed, as Flint says, "an artificial and heterogeneous conglomeration." The same authority protests against the exclusion of Metaphysics and Theology, a procedure common to Comte, Spencer, and Bain; but concedes that as regards the classification of the Sciences properly so-called Bain's Scheme "may well be regarded as an improvement on Comte's and much superior to Spencer's."

Karl Pearson's Classification.—One of the clearest of recent maps of knowledge is that furnished by Prof. Karl Pearson in his *Grammar of Science.* He distinguishes, to begin with, the Abstract Sciences, which deal with modes of discrimination, from the Concrete Sciences, which deal with the contents of perception. The Ab-

stract Sciences include Logic and other "methodological" disciplines, and mathematics with its many subdivisions including Statistics.

The Concrete Sciences include (1) the Physical Sciences, which deal with inorganic phenomena, and (2) the Biological Sciences, which deal with organic phenomena. The Physical Sciences are divided by Pearson into the Precise and the Synoptic, the latter always decreasing as the former increase. Astronomy is in greater part precise, meteorology is in greater part synoptic. "In the one case we have not only a rational classification of facts, but we have been able to conceive a brief formula, the law of gravitation, which accurately resumes these facts. We have succeeded in constructing, by aid of ideal particles, a conceptual mechanism which describes astronomical changes. In the other case we may or may not have reached a perfect classification of facts, but we certainly have not been able to formulate our perceptual experience in a mechanism or conceptual motion, which would enable us to precisely predict the future."

(1) The Physical Sciences—those dealing with Inorganic Phenomena—are divided by Pearson into the following:—

Precise Physical Sciences (reduced to ideal motions).

Physics of the Ether, *e. g.* dealing with Heat, Light, Electricity, Magnetism.
Atomic Physics, *e. g.* Theoretical Chemistry, Spectrum Analysis.
Molecular Physics, *e. g.* dealing with Elasticity, Sound, Crystallography, Hydro-mechanics, Theory of the Tides, Kinetic Theory of Gases.
Molar Physics, *e. g.* Mechanics, Planetary Theory, Lunar Theory.

Synoptic Physical Sciences (not reduced to ideal motions).

Chemistry, Mineralogy, Geology, Geography, Meteorology, Inorganic Evolution of the Earth and the Planetary System.

The *Precise* and the *Synoptic Physical Sciences*, respectively, "correspond very closely to the phenomena of which we have constructed a conceptual model by aid of elementary corpuscles having ideal motions, and to the phenomena which have not been reduced to such a conceptual description." . . . "Thus *Synoptic Physical Science* is rather *Precise Physical Science* in the making than qualitatively distinct from it. It embraces large classifications of facts which we are continually striving to resume in simple formulæ or laws, and, as usual, these laws are laws of Motion. Thus considerable portions of

the *Synoptic Physical Sciences* are already precise, or in process of becoming precise. This is notably the case with Chemistry, Geology and Mineralogy.

(2) THE BIOLOGICAL SCIENCES—those dealing with Organic Phenomena—are divided by Pearson as follows:—

First, there are those branches of biological science which deal with the spatial relations, or the localization of living creatures. Here Pearson includes the study of the *Distribution of Living Forms* (*Chorology*) and the study of habits in relation to environment (*Ecology*). "These form the major portion of what in the old sense was termed *Natural History*." [Prof. Pearson's classification seems to us, in this instance, too hard and fast. The distinctive feature of animal behaviour is certainly not its spatial relation.] Secondly, there are those branches of biological science which deal with sequence in time—with growth or change. The non-recurring phases are called Evolution (of plants, animals, and man); the recurring phases are called Growth. The study of non-recurring growth is *History;* the study of recurring growth is *Biology* in the narrower sense. [This seems to us again too hard and fast. Thus we do not think that the *transformation through variation and selection* which is at the heart of racial evolution, and the *differentiation and integration* which are at the heart of

individual development, can be lumped in the conception of Growth.]

Biology is further subdivided, by Pearson, into three great divisions, according as it deals (*a*) with *form* and *structure* (Morphology, Anatomy, Histology, etc.); (*b*) with *growth* and *reproduction* (the topics dealt with in the Evolution of Sex, the Theory of Heredity, and Embryology); and (*c*) with *functions* and *actions*, which may be studied from the physical side (Physiology) or from the mental side (Psychology). The branch of Psychology which deals with men in the group is Sociology, which falls into such branches as the Science of Morals, the Science of Politics. Political Economy, and Jurisprudence.

PEARSON'S SCHEME

(In outline only.)

ABSTRACT SCIENCE:—Logic. Mathematics, Statistics, Applied Mathematics, a cross-link between Abstract and Concrete Science.

CONCRETE SCIENCE:—(1) The Physical Sciences —including *Precise Physical Sciences* (Physics of the Ether, Atomic Physics, Molecular Physics, Molar Physics) and *Synoptic Physical Sciences* (Chemistry, Mineralogy, Geology, Geography, Meteorology, etc.).

(2) The Biological Sciences—including

Chorology and Ecology, Biology in the narrower sense (the study of structure, the study of growth and reproduction, the study of functions, Psychology, and Sociology, and finally History (including the study of organic as well as human evolution).

Bio-physics.—To his long list of sciences Prof. Pearson would add another—a cross-link between *Physical* and *Biological Sciences*—which he calls Bio-physics. This science particularly excites our interest, for in spite of its very shadowy nature (even Pearson admitting that it "does not appear to have advanced very far at present") the idea of it is provocative and raises the kind of question which makes the problem of classifying the sciences of deep importance.

Prof. Pearson says that "life invariably occurs associated with sense-impressions similar to those of lifeless forms," and that "organisms appear to have chemical and physical structure differing only in complexity from inorganic forms." But our impression is that the difference in complexity has involved a difference in kind, such that the interpretative formulæ of the physical sciences do not suffice for the description of the growth and activities, the development and evolution of organisms. Living creatures are historic beings,

and in studying them we have to do with behaviour quite different from the movements of lifeless forms. Prof. Pearson continues:—

"Although we cannot definitely assert that life is a mechanism, until we know more exactly what we mean by the term mechanism as applied to organic corpuscles, there still seems little doubt that some of the generalizations of physics—notably the great principle of the conservation of energy—do describe at least part of our perceptual experience of living organisms."

Admitting this, and the fact that there are physical and chemical processes in the living body which receive physical and chemical formulation, we do not regard these as distinctive of the living creature. Many of them, such as digestion, may occur outside the living body altogether, in a test-tube for instance. In short, we do not find that a knowledge of these isolated items helps us to describe in physical terms the life and behaviour, the development and evolution of living creatures.

According to Pearson, however, "a branch of science is needed dealing with the application of the laws of inorganic phenomena, or Physics, to the development of organic forms. This branch of science which endeavours to show that the facts of *Biology*—of *Morphology*, *Embryology*, and *Physiology*—constitute particular cases of general

physical laws has been termed *Etiology*. It would be perhaps better to call it *Bio-physics*."

But the term Etiology is already in recognized use for a biological inquiry into the factors in organic evolution, such as variation and heredity, selection and isolation, and it will remain a sound branch of the biological tree even though no success rewards the attempt to describe evolution in terms of the laws of physics.

Prof. Pearson's idea is different. Just as *Applied Mathematics* is "the process of analysing inorganic phenomena by aid of ideal elementary motions," and thus links Abstract to Concrete Science, so *Bio-physics* attempts to link the Physical and Biological Sciences together.

Pearson presents this view in a scheme:—

Applied Mathematics —a cross-link	ABSTRACT SCIENCE CONCRETE SCIENCE

PHYSICS BIOLOGY

Bio-physics—a cross-link

"*Applied Mathematics* and *Bio-physics* are thus the two links between the three great divisions of

Science, and only when their work has been fully accomplished shall we be able to realize von Helmholtz's prediction and conceive all scientific formulæ, all natural laws, as laws of motion. This goal we must, however, admit is at present indefinitely distant."

Not only so, but as the only Bio-physics we know of is the physical and chemical study of various processes that occur in organisms, and as no vital function whatever has yet been re-described in bio-physical terms, and as the results of bio-physical analysis do not seem to help us to understand the growth and activities, the development and evolution of living creatures which require interpretations different in kind from those of Physics—we are of opinion that Bio-physics might be completed without Biology having more than begun.

It is greatly to be regretted that an elaborate and vividly clear classification of the sciences by Prof. Patrick Geddes has not yet been published, and therefore cannot be included here, though the most convincing one we know. Some indication of it may be obtained from the following scheme of anthropological studies published in 1903 by Prof. A. C. Haddon, for which he was largely indebted to Prof. Geddes:—

Exact Science.—We have seen that Prof. Karl Pearson has distinguished Precise Physical

		"Historical"	"Morphological"	"Physiological"	"Ætiological"
Ethnology (Sociology)		Archæology	Social Taxonomy	Economics and Politics	Philosophy of History
		Evolution of Institutions and Technology	Analysis of Institutions and Technology	Functioning of Occupations and of Institutions Linguistics	Criticism of Institutions
Anthropology	Racial	Palæontology of Man	Racial Classification of Man	Anthropological Ecology	Rational Phylogeny
	Individual	Comparative Human Embryology	Comparative Human Anatomy	Comparative Human Physiology	Rational Ontogeny
Biology . .	Racial	Palæontology	Taxonomy	Ecology	Rational Phylogeny
	Individual	Embryology	Anatomy	Physiology	Rational Ontogeny

Sciences from Synoptic Physical Sciences. In the former, such as Molar and Molecular Physics, the processes can be described in terms of ideal motions; in the latter, such as Chemistry and Geology, this can be done only in part. But portions of the Synoptic Sciences are always passing into the Precise Sciences.

The term "Exact Science" may be used more generally to indicate all science that has resolutely begun to "measure," including in "measurement" all forms of precise registration. Not a little of the modern work in pyschology is very exact, but the description of its subject-matter "in terms of ideal motions" is certainly not its end.

In further illustration, let us ask why we hesitate in applying to Biology the term "Exact Science" which we unhesitatingly accord to Astronomy. The reasons are two,—intrinsic and extrinsic. The intrinsic reason is that Biology deals with living creatures, which are personal agents, variable and spontaneous, always to some extent unpredictable. We deal in Biology with an order of phenomena more complex than in Astronomy, and our knowledge is proportionately lacking in exactness.

The extrinsic reason is that Biology is a young science and Astronomy a very old one. The Astronomer is a master-workman, the Biologist

still only an apprentice. In a lecture on Inheritance, the late Prof. W. F. R. Weldon put this matter very clearly: "The ideal description of every experience, the description which alone makes further progress possible, is a description of *all* the results obtained, and not a statement which largely ignores the inconsistencies observed. The reason why astronomers, and physicists, and chemists can so often afford to neglect the inconsistencies of their experience without making themselves ridiculous is that by great labour they have already succeeded in confining the limits within which these inconsistencies occur, so that the proportion of the whole experience affected by them is very small. But biologists have not yet advanced so far as this: The margin of uncertainty in their experience is still so large that they are obliged to take account of it in every statement they make."

Yet the work which Prof. Weldon himself did in connection with variation, heredity, and selection was symptomatic of the movement towards exactness that has recently characterized even the most difficult departments of Biology, those dealing with Evolution. There has been for a long time much exact science in comparative anatomy and physiology, but in recent years the labours of the biometricians on the one hand, and of the experimental zoologists

on the other, have done much to bring the study of evolution-problems nearer the ideal of exact science.

Classification Adopted.—Combining what appear to us to be the chief merits of the foregoing classifications, we propose the following map:—

A. Abstract, Formal, or Methodological Sciences.

These deal with methods of inference, supply intellectual instruments for investigation, and test the consistency and completeness of scientific descriptions.

Mathematics, including Statistics.
Logic, in the widest sense.
Metaphysics.

B. Concrete, Descriptive, or Experiential Sciences.

These deal with the facts of experience and with inferences from these facts. They include five general or fundamental sciences and a large number of particulate or derivative sciences.

B. 1. The five great fundamental sciences are:—

SOCIOLOGY	ANIMATE ORDER
PSYCHOLOGY	
BIOLOGY	
PHYSICS	PURELY PHYSICAL ORDER
CHEMISTRY	

SOCIOLOGY is the science of the structure and life, growth and evolution of societary forms or social groups.

PSYCHOLOGY is the science of the subjective aspect of behaviour, of Man and of animals. In the human sphere Psychology has the fascinating distinction, as compared with other sciences, that "the instruments of investigation are also the objects of research."

BIOLOGY is the science of the structure and activity, development and evolution of organisms, including Man.

PHYSICS is mainly the science of the transformations of Energy (Energetics).

CHEMISTRY is mainly the science of the different kinds of matter, their transformations, affinities, and interactions. It is *par excellence* the science of molecules and atoms.

CLASSIFICATION ADOPTED.

ABSTRACT SCIENCES.	CONCRETE SCIENCES.			
	GENERAL.	SPECIAL. (Examples	COMBINED. only can be given in	APPLIED. the space.)
METAPHYSICS (SUPREME)	V. SOCIOLOGY	ETHNOLOGY STUDY OF INSTITUTIONS	SCIENCE OF HUMAN HISTORY	POLITICS CIVICS ECONOMICS
LOGIC	IV. PSYCHOLOGY	ÆSTHETICS LINGUISTICS PSYCHO-PHYSICS	ANTHROPOLOGY	ETHICS EDUCATION
STATISTICS	GENEO-LOGY | MORPHO-LOGY | PHYSIO-LOGY | AETIO-LOGY III. BIOLOGY	ZOOLOGY BOTANY PROTISTOLOGY	GENERAL HISTORY OF THE BIOSPHERE	EUGENICS MEDICINE FORESTRY
MATHEMATICS (FUNDAMENTAL)	II. PHYSICS	ASTRONOMY GEODESY METEOROLOGY	GENERAL HISTORY OF THE EARTH GEOLOGY GEOGRAPHY	NAVIGATION ENGINEERING ARCHITECTURE
	I. CHEMISTRY	SPECTROSCOPY STEREO-CHEMISTRY MINERALOGY	OCEANOGRAPHY GENERA L HISTORY OF THE SOLAR SYSTEM	AGRICULTURE METALLURGY MINING

It must be admitted that the fields of chemistry and physics are not separated by any defensible boundary-lines, and the two sciences obviously come together in such studies as spectrum analysis and in such theories as the electric structure of the atom. But the distinction is one of considerable convenience and will probably last.

Some would have even more doubt as to the propriety of separating off Sociology, from Psychology for instance.

The fact is that Sociology is still a very young science; its scope and definition are in its own hands. It is therefore neither necessary nor advisable at present to try to define it with precision; we must see first how far it can go. It is the scientific study of social groups or "societary forms," considered as concrete organic unities,—each of them more than the sum of its parts. It necessarily comes into contact with anthropology and history, with economics (which has primarily to do with industrial organization), and with politics (which has primarily to do with the affairs of the state as such), but it has a place and function of its own.

B. 2. The most important derivative or particulate sciences may be arranged in groups, dependent on the five fundamental sciences. Two points have to be kept clearly in mind, and may

be best illustrated by examples. (*a*) While the general or fundamental science of Biology is not concerned with the kinds of Plants or Animals, the particulate or derivative sciences of Botany and Zoology emphatically are. (*b*) Many of the derivative sciences are complex or synthetic, Anthropology being a good example. They combine the methods and concepts of several of the fundamental sciences for their own particular purposes. Thus, to take another case, Geology is a synthetic science, the focussing of several sciences in the study of the Earth. It inquires into the structure, activities, and history of the Earth, which it conveniently divides into four shells—each, if we like, with its special science—the atmosphere, the hydrosphere or oceans, the lithosphere or crust, and the centrosphere or nucleus. For the most part, perhaps, geologists are concerned with the earth's crust, but there are few of them who would consent to be restricted to this territory. As Prof. R. S. Woodward says: "Geology illustrates better than any other science, probably, the wide ramifications and the close inter-relations of physical phenomena. There is scarcely a process, a product, or a principle in the whole range of physical science, from physics and chemistry up to astronomy and astrophysics, which is not fully illustrated in its uniqueness and in its diversity by actual operations still in

progress on the earth, or by actual records preserved in her crust. The earth is thus at once the grandest of laboratories and the grandest of museums available to man."

Another idea which seems useful is that of *sub-sciences*, as distinguished from special sciences. Let us explain with reference to Biology. (i.) A general or fundamental science is distinguished partly by its subject-matter, *e. g.* living organisms; and partly by its point of view, which, in the case of Biology, for instance, is not the physico-chemical point of view. A general science has a well-defined subject-matter to which it applies characteristic methods and concepts. Furthermore, it is concerned with general questions and not with particular descriptions. Biology is concerned with what is common to all living creatures, and with averages, not individuals.

(ii.) But under the rubric of Biology we have the special, particulate, or derivative sciences of Botany and Zoology, which divide the world of organisms between them and are both concerned with particular description as well as with general formulation. It might also be convenient to have a special science of Protistology for the minute and simple organisms which seem to hesitate between plant and animal life. And other special sciences may be recognized if desired. It is all a matter of convenience.

(iii.) But within the general science of Biology several quite different questions are asked, and the answers to these are the sub-sciences. The questions that the biologist must ask and answer before he can go far in generalization appear at first sight to be very numerous and varied, but, from a certain distance, we see that there are only four: What is this living creature as regards form and structure? How does it work? Whence has it arisen? How has it come to be as it is?

(1) What is this in form and structure, in symmetry and internal architecture? It seems a "simple question," but how hard to answer, as we press it farther and farther home, as we pass from external features to internal structure, from organs to tissues, from tissues to cells, as we put one lens after another in front of our own, as we call to our aid all sorts of devices—scalpel and forceps, razor and microtome, fixative and stain! "What is this," we say, "in itself and in all its parts? what is this by itself and when compared with its fellows and kindred?" and our answer broadens and deepens till it furnishes the raw materials of the sub-science of morphology.

(2) Close upon the first question—What is this? there rises a second—How does this work? "It is equally natural and necessary, and throughout the progressive periods in the history of Biol-

ogy the two questions have never been far apart. They have evolved together, especially during the last hundred years, prompting one another to a more and more penetrating inquisitiveness. The key-word of the one is structure, or organization; the key-word of the other is function, or activity. The creature which our first question killed and picked to pieces has to be put together again and made to work! What does it do? how does it do it? how does it go? how does it keep agoing? how does it set other creatures like itself agoing? how long can it go? how does it cease from going? In other words, how does the organism feel and move? how does it grow and multiply? how does it waste, recover itself, and finally, in most cases, die? Above all, what is the secret of its activity and of its power of effective response to the changeful order of nature?" (*Darwinism and Human Life*, 1909, p. 8.) The attempts to answer these and similar questions have made the science of Physiology.

Physiology is the science of the activity of organisms. It is the study of the working of living things. It considers plants and animals and man in their dynamic relations, just as morphology considers them statically. It takes to do with habit and function, just as morphology takes to do with form and structure. And the

two sister sciences go hand in hand, for just as taking a watch to pieces is not very intelligent unless we inquire into the working of the various parts, and just as we cannot understand how the watch "goes" unless we know its structure intimately, so anatomy and physiology must always be closely linked together.

There has been a close parallelism in the history of the two sciences. The morphologist began with the form of the intact organism, and passed in succession to the various organs, their component tissue, their component cells, and, finally, to the structure of living matter itself. So the physiologist investigates life or activity at different levels, passing from his study of the living creature as a unity with certain habits, to consider it as an engine of organs, as an intricate web of tissues, as a veritable community of cells, and, finally, as a whirlpool of living matter.

(3) The third question—Whence is this? is really double, for we may inquire into the development of the individual (Embryology) or into the history of the race as it is hidden in the strange graveyards of the buried past, the fossil-bearing rocks (Palæontology). Since these are both historical or genetic inquiries, the one dealing with individual development (ontogeny), the other with racial evolution (phylogeny), it would

be useful to have one word like "geneology" (altering a letter in genealogy) to cover them both.

(4) There remains a fourth question, since Darwin's day asked with a new hopefulness—How have these living creatures come to be as they are? What are the originative and what the directive factors in evolution? How has the raw material of progress, which we call variations, been made available throughout the countless ages? and how has this raw material been fashioned to shape and use in improved adaptations and endless new departures? The attempts to answer these and similar questions are laying the foundation-stones of the young sub-science of Ætiology.

The primary sub-sciences of Biology are thus four:—

Morphology, the study of static relations, of form and structure.

Physiology, the study of dynamic relations, of habit and function.

Geneology, the study of development or of individual becoming (Embryology), or of the rock-recorded facts of racial history (Palæontology).

Ætiology, the study of the factors in racial evolution.

It is evident that these sub-sciences of Biology appear also as particular questions or methods of the special sciences of Botany and Zoology.

$$\overbrace{\boxed{\text{GENEOLOGY}}\boxed{\text{MORPHOLOGY}}\boxed{\text{PHYSIOLOGY}}\boxed{\text{ETIOLOGY}}}^{\text{BIOLOGY}}$$

For purposes of convenience it seems well to retain the term "Applied Science" for any department of a "Special Science" which has directly to do with the arts and crafts. Thus, to take a familiar illustration, a great part of "Medical Science" is "Applied Science" definitely orientated in relation to the art of healing. This "Medical Science" is, or may be, just as scientific as anything else; it is so in direct proportion to the soundness of its foundations in Anatomy, Physiology, Biology, Chemistry, and the like, and in direct proportion to its own scientific industry, but not even its most enthusiastic devotees will maintain that it aims directly at adding to the sciences on which it is based. It does so illustriously, it is true, but incidentally, and it is a fine example of what we may legitimately call an "Applied Science."

Another very clear example is "Agricultural Science," which is orientated in relation to farming, gardening, shepherding, and the like. It is,

or may be, just as scientific as any other department; it is so in direct proportion to the soundness of its scientific foundations in Chemistry, Botany, Zoology, Geology, Biology, and the like, and in direct proportion to its own scientific industry, but not even its most enthusiastic devotees will maintain that it aims directly at adding to the sciences on which it is based. It has begun to repay its debts, but not deliberately. It is a fine example of an "Applied Science."

Many other examples might be given, such as the Science of Education and the Science of Engineering, both of which appear to us to be "Applied Sciences," intermediate between a general or a particulate science (a "pure science") on the one hand and one of the Arts or Crafts on the other. Their obviously distinctive feature is that they contain a large body of knowledge definitely orientated towards a practical purpose.

THE INTEREST OF THE CLASSIFICATION OF THE SCIENCES.—It may seem to some that, for a small book of this sort, too much space has been given to a very "academic" question,—that of the classification of the sciences. But may we briefly indicate its real interest. (*a*) Perhaps it does not matter very much which classification is adopted, the important thing is to have in the mind some classification which one has made one's own. It is not merely that we should put our

intellectual house in order—a process that tends to clear thinking, but to have a vividly real scheme or map of knowledge is to have a sort of Philosopher's Stone. It adds to the value of our knowledge by always suggesting inter-relations and by serving as a test of completeness and consistency. We all need to be constantly reminded of Plato's demand that the true lover of science shall be interested in *the whole of his subject.*

(*b*) The second great interest of the classification of the sciences is that it raises the largest and deepest questions. Willy-nilly it expresses a Philosophy. Its boundary-lines express our conclusions as to the autonomy or the dependence of Biology and of Psychology, our decisions on the difficult questions of Vitalism and Materialism. It is not a matter of indifference whether Sociology should be reckoned as a general science (Comte) or as a branch of Biology (Pearson). It is not by a misprint that we have placed Metaphysics beside Mathematics as an Abstract Science.

As we think over the conflicting classifications of the sciences, we see that a frequent cause of confusion has been the attempt to map out territories as preserves of particular sciences. This implies a wrong idea of the constitution of a science, which is defined not by its subject-matter, but by the categories under which it thinks of

that subject-matter. Two sciences may work and often do work at the same material,—but with different ends in view, with different fundamental concepts, and with methods different in detail.

Let us illustrate. An anthropologist may work for years at a particular societary form, and yet his results may be contributions to biology rather than to sociology. A psychologist may devote himself to the study of cats and dogs, and yet his results may not be contributions to biology in the stricter sense. A physicist may give persistent and profitable attention to the electrical changes associated with contracting muscle, and yet though he is in a sense dealing with organisms all the time, his results may be contributions to physics rather than to biology. Similarly, the chemist, for purposes of his own, may give his life to the study of the odoriferous substances in flowers, and yet never ask one biological question.

The Correlation of the Sciences.—From the classification of the sciences and sub-sciences we turn with a feeling of relief to the idea of their Unity. Blocked apart for practical convenience, treated of in separate books, expounded by different teachers, investigated in different laboratories, the sciences are, after all, parts of one discipline, illustrations of one method, attempts to make clear—if never to solve—the one great problem of the Order of Nature. They

form, or should form, one body of truth, and they gain in value the more they are correlated. This is the ideal alike of the Philosopher's Stone, of the Encyclopædia, of the University, and of the most modern scientific synthesis. Let us briefly consider it from various points of view.

When we think of a living creature with vividness, several major impressions stand out clearly in the mind. In the first place, the organism is a unity. It has many members, but one body; many activities, but one life. It develops and grows and varies and acts as a unity. Therefore, we feel sure that while it has to be made the subject of many different sciences,—anatomy, physiology, embryology, not to speak of chemistry and physics, and not forgetting psychology, the scientific truth about the living creature cannot be reached unless the results of the various scientific inquiries are pooled, and unless the fundamental fact of the unity of the organism is recognized.

In the second place, the living creature cannot be isolated or studied *in vacuo.* It has an inanimate environment from which it is scientifically inseparable, and it sends its tendrils into the lives of many other creatures. If we are to come nearer knowing the truth about the living creature, we must study it in its inter-relations. But that involves the convergence of many sciences, which

approach their ideal completeness in proportion as they are correlated.

In the third place, we have to bear in mind that the living creature is passing by as one of a great historical pageant. It is an heir of the ages, only to be understood as the resultant of numberless factors—mechanical, chemical, physical, and animate—which have gone to its shaping. It has gathered into itself the sunshine and haar, the wind and the rain of millennia. It requires a unity of the sciences if it is to be understood. Nor is it merely a passer-by in a great procession, which we can study all too briefly before the torch it carries goes out and it fades away, it is an individualized phase in the ceaseless circulation of matter and energy. To change the metaphor again, it is a whirlpool in the river of time. All of which makes us feel that the sciences are most scientific when they are most united. The higher the subject in the scale of being the more obvious this is, for Man most of all, but even in regard to the non-living the inter-relatedness of things makes a unification of sciences necessary. Who, for instance, can understand the earth as it is apart from its living tenants? The very dust throbs with life.

The idea which we wish to illustrate is very plain when we think of some big problem such as the physiology of marine organisms—and the

improvement of fisheries as an application of this. The only hope of getting towards an understanding of such a subject is through the combined efforts of chemist and physicist, botanist and zoologist, meteorologist and geographer.

Worthy of note in this connection is the unthought-out objection which some ultra-conservative educationists bring against geography, that it is not a well-defined single science, but a combination of many sciences for a particular purpose. The description is correct that Geography is a circle cutting many other circles, but this is precisely its peculiar scientific merit and virtue, that it expresses a unification or synthesis of complementary disciplines.

Our intellectual outlook on the world depends on our scientific culture, and its value must vary with the all-roundness and with the correlation of different scientific disciplines. Just as it takes many different rays of light to make sunshine, so it takes many different sciences to give that synthetic view which we call sanity. Thus we stand in unwearying admiration before Goethe because his outlook was at once physical and biological, geographic and psychic.

It is idle to pretend that the outlook on the order of nature which becomes habitual to the student of mechanics has nothing to gain from, let us say, the very different impressions that

reward those who devote themselves to comparative psychology. It savours of what we may call scientific Chauvinism to maintain that physico-chemical interpretations, when they go to the formation of our outlook on Nature, require no corrective from the biological, mental, and social sciences. It requires a long-necked observer to see the whole firmament out of one window.

We know how chemistry assists in physiological inquiry; showing how this and that chemical process occurs in the body, here an oxidation and there a reduction, now a hydrolysis and again a fermentation, thereby bringing into stronger relief the co-ordination and control of all these, which is distinctively vital. But we have also to notice how physiology assists chemistry,—a noteworthy instance being the physiological discovery of oxygen by Mayow (1674) a century before the element was chemically isolated.

The point that we wish to get perfectly clear is this, that the same phenomenon may be considered without irrelevancy under several sciences. Thus when we enjoy looking at a rose, there are chemical, physical, physiological, and psychological problems involved. At least four sciences have something to say, and what must be realized is that while these sciences are separated off for purposes of human convenience, because they

pursue different methods, use different tools, sum up in different kinds of formulæ, they are simply different modes of one rational inquiry.

Summary.—*The classification of the sciences is in detail a matter of convenience, but it is of great practical importance to have in the mind some clear map of knowledge. The broad lines of the classification depend upon our scientific and philosophical convictions*, e. g. *as to the independence of Biology and the separateness of Psychology from Physiology. It seems useful to separate, first of all, the abstract sciences which are "methodological," from the concrete sciences which deal with the facts of experience. The fundamental abstract science is Mathematics, and we would regard Metaphysics as supreme in the same division. The five great concrete sciences, which may also be called descriptive or experiential, are: Chemistry, Physics, Biology, Psychology, and Sociology. Within these there are sub-sciences,—thus Biology is divisible into Morphology, Physiology, Geneology* (i. e. *Embryology and Palæontology) and Ætiology. Dependent on the five general sciences are the numerous derivative or particulate sciences, such as Botany and Zoology. Many of these are complex or synthetic, focussing several sciences on one subject: Geology and Geography are good examples. The term "applied science" is conveniently used for those departments of general or special sciences which have directly to*

do with the development and evolution of human life, or the arts and crafts. It is a matter for discussion whether there is only one science of Nature or whether it is truer to say that there are several, but all are agreed that the value and the progressiveness of the sciences depends in part on the degree of their correlation.

CHAPTER V

SCIENCE AND PHILOSOPHY

"Truth is on a curve whose asymptote our spirit follows eternally."—Leo Errera.

The Aims of Science and Philosophy—Twofold Relation between Science and Philosophy—Limitations of the Scientific Account of Things—Problems before which Science and Philosophy Meet—Origin of Living Creatures upon the Earth—The Secret of the Organism—An Illustration—The Soul and Body Problem—A Question—Summary.

The Aims of Science and Philosophy.—In this little book we have emphasized the view of many modern thinkers, that it is the chief business of the experimental sciences, whether physical or psychical, to discover "descriptive formulæ by the aid of which the various processes which make up the physical and psychical orders may be depicted and calculated." The aim of science is descriptive formulation; let us ask of the philosophers how their inquiry is related to ours.

Prof. A. E. Taylor, to whose *Elements of Metaphysics* I owe a debt of obligation which I

very gratefully acknowledge, states the difference between Science and Philosophy as follows:—

"The work of the Philosophy of Nature and of Mind only begins where that of the experimental sciences leaves off. Its data are not particular facts, as directly amassed by experiment and observation, but the hypotheses used by experimental science for the co-ordination and description of those facts. And it examines these hypotheses, not with the object of modifying their structure so as to include new facts, or to include the old facts in a simpler form, but purely for the purpose of estimating their value as an account of ultimately real existence. Whether the hypotheses are adequate as implements for the calculation of natural processes is a question which Philosophy, when it understands its place, leaves entirely to the special sciences; whether they can claim to be more than useful formulæ for calculation, *i. e.* whether they give us knowledge of ultimate Reality, is a problem which can only be dealt with by the science which systematically analyses the meaning of reality, *i. e.* by Metaphysics. We may perhaps follow the usage of some recent writers in marking this difference of object by a difference in terminology, and say that the goal of experimental science is the Description of facts, the goal of Metaphysics their Interpretation. The difference of aim is, how-

ever, not ultimate. Description of facts, when once we cease to be content with such description as will subserve the purpose of calculation and call for description of the fact as it really is, of itself becomes metaphysical interpretation."

We have seen that one of the aims of science is to distinguish what "seems" from what "is," and to do so generally, not particularly, is the chief task of metaphysics. "Metaphysics sets itself more systematically and universally than any other science, to ask what, after all, is meant by being *real*, and to what degree our various scientific and non-scientific theories about the world are in harmony with the universal characteristics of real existence. Hence, Metaphysics has been called "an attempt to become aware of and to doubt all preconceptions"; and again, "an unusually resolute effort to think consistently."

Something is always going wrong, however, when the boundaries between different disciplines begin to appear static, like stone walls. The various disciplines are like the functions of an organism, which work into one another's hands, being complementary. Pigeon-holing is simply a device, part of our intellectual division of labour. Science is an intellectual inquiry with definite purposes—*e. g.* of discovering uniformities of sequence, and with definite limitations, such as that of not inquiring into the larger significance

of its results. But it often strains at its self-made leash.

Let us take an example. It is the business of the zoological evolutionist to discover what he can in regard to the actual history of the various races of animals. He has to discover, for instance, if he can, the pedigree of Mammals. But his task does not end there, he has to inquire into the factors operative in this evolution—arguing back from what is known of the laws of variation and heredity, selection and isolation. But the more complete his description becomes, the more inevitably, as it seems to us, is he led towards reflection on the evolution of Mammals as a particular chapter in a great book. It cannot be torn out and understood by itself. It came about after preparations that we dimly descry being made in the mist of millions of years ago. It came about in a natural, predetermined fashion, and at a particular stage in the history of other things, such as the Earth itself. Moreover, it was part of the preparation for the Supreme Mammal—Man himself. The evolution of Mammals, along with the august process of which it was a part, must here be seen in its larger significance—it led on even to the science which, in pursuing this thought, transcends itself.

Twofold Relation between Science and Philosophy.—(1) Those who take life easily,

sailing their intellectual craft in the lea of their particular shore of well-ascertained fact, are apt to see things in the clearness of a false simplicity. Science has come to know, they tell us, the ins and outs of the stuff the world is made of—Matter, which is built up of molecules, which are composed of atoms, which consist of corpuscles or electrons. And Science has also come to know, they tell us, the power that is resident in the world—Energy, whose measure is Force. It is a power of doing work, which is always passing from form to form without any loss or any gain. Give us Matter and Energy, they say, and we will make a world out of them. Just as the chemist can build up urea and sugar and indigo from simple substances, so Nature long ago, in some unknown hotbed, made a synthesis of proteids which combined to form small viable organisms. These multiplied, and spread themselves, and varied under the stimuli of new surroundings. Given Variations and plenty of time, Selection and Isolation can do the rest. And just as consciousness emerges at an uncertain stage in the development of the individual egg-cell, so in the history of animal organisms there was an evolution of mind. Now, far be it from us to say that there is not considerable truth in this description of what may have occurred, but it is certainly far too facile and easy-going. It slurs over gigantic difficulties and

abounds in equally large assumptions. It may be criticized first scientifically, and that is well; what remains may then be criticized philosophically, which is, for developing a fit and proper frame of mind, still better.

Now we have in Metaphysics a critical discipline in consistent thinking; it has an ideal of complete explanation; and it is able to test scientific theories with reference to this ideal formal standard. In this sense Metaphysics functions as a sublime Logic, testing the completeness and consistency of our scientific descriptions, whether of things as they are, or of the way in which they have come to be, and it is desirable for the sake of Science that it should be used. The account that a Science gives of part of the world must be not only self-consistent, and congruent with the results of other sciences, it must also submit to the formal requirements of metaphysics. *This criticism of categories and systematizations is the chief service that Metaphysics has to render to science.*

From this point of view, Philosophy has been called "scientia scientiarum"—"a science which determines the principles and conditions, the limits and relations of the sciences." But to this claim vigorous objections have been raised. For it is the strong opinion of many who have made great contributions to science, that the scientific

investigator has no right to waive the responsibility of determining "the principles and conditions, the limits and relations, of the sciences." If he cannot determine these, who can? Now it may be that the definition quoted is an unfortunate one, and the objection not without justification, but the important point is this, that the categories and systematizations of science should be criticized, and this requires expert training. It can only be done by a philosopher to whom the scientific discipline is real, or by a scientific investigator to whom the philosophical discipline is real. But it has to be done.

When a well-thought-out scientific exposition disturbs the reader's preconceptions, or takes him beyond his usual depth of analysis, he has his revenge in dubbing it "metaphysical." But this is an ignorant sneer, if metaphysics means "the critical and systematic analysis of our conceptions." It is an intellectual discipline, an actively sceptical inquiry, a criticism of categories—and it may be ranked beside Mathematics and Logic in the general scheme of knowledge.

(2) The various sciences supply partial pictures of the world—pictures taken from different points of view. It is for metaphysics to combine these pictures, not as one makes a composite photograph by placing one print on the top of another, but rather as one combines two views in a stereo-

scope. In its *constructive function* metaphysics aims at an all-round and consistent view of the whole system, and it reaches this, or should reach this, not in an *a priori* fashion, but by taking account of the raw material which the sciences furnish. *In this way Science contributes to Metaphysics.*

If Metaphysics does not intrude into the province of any particular science, and if it is not another name for a synthesis of the sciences, what is its province? All thinking has to do with facts of experience, and these form the subject-matter of the sciences. Where, then, does Metaphysics come in? The answer that will suffice for our purpose in this volume is simple enough: that Metaphysics seeks to discover the general conditions of giving a complete and consistent formulation of experience—a formulation which has its foundations in the sciences, but transcends them in an attempt to answer imperious questions which Science does not even ask.

For most men it is quite impossible to remain satisfied with the systematic descriptions which science supplies, they have to go on to form "some coherent conception of the scheme of things to which they belong," and in this they necessarily become metaphysical. Now it seems good sense that they should try to do this consciously and not at random, using the experience

of the ancient science of mental construction whose foundations were laid by Aristotle. Science brings in great wealth of raw material, but the architectural genius must be sought in Philosophy.

Limitations of the Scientific Account of Things.—The plain man's question is, Can you give an account of this? What is this modern modesty of science, that it does not pretend to explain anything? Can you give an account of these phenomena or can you not? Let us consider the limitations of the scientific account of things.

Science shows, often after much study, that a certain collocation of antecedents and no other will result in a certain collocation of consequents and no other. But the consequents are often very different from the antecedents, and we cannot say that we know how they come about. Even in an exact science like Chemistry this limitation of scientific description is well illustrated. We know that oxygen and hydrogen unite under certain conditions to form something qualitatively very different from either of them, viz. water, but we do not know how it is that water results. Even in more complex cases, we know the conditions of the combination, and we have ingenious theories as to how the elements involved change partners and form new linkages, but we do not really understand how the result should be as it is. Still less can we predict what will ensue from the

previously untried combination of two highly complex substances. It is like an untried experiment in Heredity.

It comes to this: that the only cases in which we can say that our scientific account is complete and absolutely satisfactory, are cases of mechanics—most beautifully in Gravitational Astronomy—where the resultant is just a new form of the components. Then only can we say with a clear intellectual conscience, "Causa æquat effectum." Science is continually showing that one particular collocation of matter and energy passes into another, but when the chains of sequence that it chronicles are intricate it is no longer plain that the resultant must be as it is and not otherwise.

Again, the terms of scientific interpretations are not self-explanatory. The biologist's cheques are backed by "Organism," "Protoplasm," "Heredity," and so on, and no one can suppose that these are self-explanatory terms. Some term of this sort may be an absolutely necessary postulate in Biology, but it obviously means starting with a great deal "given." And when we pass to more exact sciences, and find the cheques backed "Gravitation," "Chemical Affinity," and so on, we must again recognize that a good deal is taken as "given."

It may be said, however, that these terms of description are continually undergoing a process

of simplification, and that is true. "Heat" and "Light" have yielded to simplifying analysis; perhaps "Chemical Affinity" is at present yielding; perhaps the physicist may some day discover the true inwardness of Gravitation, and be able to tell us what really happens in the invisible world when the apple falls in the orchard. It is the aim of Science to reduce the number of absolutely necessary concepts, but it does not in so doing make those that remain any simpler. "Matter" and "Energy" or other terms of the same order of magnitude are always, as it were, expanding as others are forced into them, and remain as fundamental terms which are not self-explanatory.

Taking "matter," for instance, which has seemed to some the most trustworthy bedrock on which to base their theoretical reconstruction of the world, what a visionary thing it has become in the hands of modern physics. The founders of the molecular theory laid down the idea that each kind of matter has its characteristic kind of particle; Dalton showed that we must think of these molecules as built up of atoms; modern work is suggesting that there may be a common basis for matter of all kinds, as if the different kinds of atoms consisted of different numbers of smaller corpuscles of the same kind. These are the negatively electrified particles—the corpuscles

or electrons which all bodies give off under suitable treatment, such as raising to incandescence or exposure to ultra-violet light. The atom is now supposed to be built up of units of negative electricity and of an equal number of units of positive electricity, of very much greater mass, the number of either kind being proportional to the atomic weight; and the whole system is in a state of equilibrium or of steady motion.

We must understand, however, that this electrical theory of matter is far beyond verification, that it makes big assumptions, and that it leaves many difficulties. Prof. Poynting writes in regard to it: "The chief value of such a hypothesis lies, not in its objective truth, but in its success in accounting for, in co-ordinating, what we actually observe, and in predicting results which are afterwards verified. It is to be regarded as a 'working model' which gives the same results as the actual atom, though, it may be, by quite different machinery."

So that, after all, the theory of the electric atom does not do more than represent the unknown reality in a faithfully symbolical matter. It is a working thought-model. But how far we are getting from the old "matter" of the naïve materialists. And yet the difficulties have only begun, for the matter of physical analysis is an abstraction, whereas the matter of our direct experience

is in certain conditions the physical basis of "life" and the home of the "soul." And beyond this there is the philosophical aspect of the problem of matter.

As in its analytic so in its historical treatment of things Science must confess its limitations. It begins, not at the beginning—that is impossible, but from something "given," which it does not explain, which in the last resource it cannot explain. From this something given—say primitive Amœbæ—much seems to have been evolved, and Biology seeks to discover both the stages and the operative factors in the evolution. But if the primitive Amœbæ gave rise "in the natural course of events" to higher organisms, and these to higher, until there emerged the supreme Mammal, who by and by had a theory of it all, then the primitive Amœbæ which had in them the promise and potency of all this were very wonderful Amœbæ indeed. There must have been more in them than met the eye! We must stock them with initiatives at least. We are taking a good deal as "given."

Finally, it must be recognized that the terms of scientific descriptions in their higher reaches are "conceptual formulæ." We speak glibly of "Matter," "Energy," "Ether," "Atom," and so on, but these are intellectual counters, rather than the realities themselves. They are, so to

speak, counterfoils or symbols of reality. We may well say of them what Hobbes said of words: "They are wise men's counters, they do but reckon by them, but they are the money of fools."

Yet we must not react too far from the realism of old-fashioned Science! For while it is true that Science only gets at fractions of reality, and that it works with formulæ and intellectual counters, scientific conclusions are none the less trustworthy indices of what does actually happen. Otherwise we could not use them as a basis for safe prophecy. No one knows what matter, gravitation, inertia, and so on, really are; but the established formulations which deal with them have certainly a close correspondence with reality. We need not do more than refer to the familiar but astounding fact that, given three good observations of a comet, and we can prophesy with absolute certainty when it, barring accidents, will return!

Problems before which Science and Philosophy Meet.—The world is full of unsolved problems—which give it part of its charm and interest, and there is no prospect of the supply running short. Some of these unsolved problems are scientific, and he is rash indeed who will call any of them insoluble. Many of the insoluble problems of our forefathers have their solutions stated in our text-books, and Science is still very

young. Moreover, some of the very difficult unsolved problems are already being nibbled at by scientific methods, which in itself is hopeful.

Every one must admit, however, that we are confronted with a number of problems in regard to which we find it difficult to think with clearness, and in regard to which we seem to make little progress. We refer to problems like that of the origin of living organisms upon the earth, or that of the living body as contrasted with an inanimate system, or that of the relation of soul and body. In reference to those and similar problems Science has certain contributions to make, but these have tended to increase rather than lessen the difficulties of the situation. Thus it is much more difficult for us to believe in spontaneous generation than it was for Harvey; it is much more difficult for us to accept a mechanistic physiology than it was for Descartes.

Now in regard to these very difficult problems we should at least know where we stand, and the scientific answer must be "Ignoramus." In regard to a problem like the origin of life the only scientific position at present is one of agnosticism. For most minds, however, the consistently agnostic position is difficult. As scientific inquirers we piously adhere to it, but when we go out into the street we speculate with the best of them. We make hypotheses, the pros and cons of which

can be discussed, and we pass insidiously from Science to Metaphysics. It is in the criticism of these hypothetical constructions, which avowedly go beyond verifiable science, that philosophical criticism is of great value. Let us say a little, then, in regard to two or three of the problems before which Science and Philosophy meet.

Origin of Living Creatures upon the Earth.—In the volume on Evolution in this Library, there is a brief discussion of this old-standing problem, to the solution of which we do not seem to be coming any nearer. We know that the hot Earth must have been tenantless, that until it cooled and consolidated it was quite unfit to be a home of life. But we do not know how living organisms began to be upon the earth.

Did germs of life come to our earth embosomed in meteorites—*from elsewhere*, or had they their cradle here—the offspring of inorganic evolution? We do not know. May it have been, as Pflüger and Verworn have suggested, that the cyanogen radical (CN) was the starting-point of the proteid molecule which is an essential constituent of the physical basis of life? We cannot discuss the matter, but we must remember (1) that although the synthetic chemist can do wonders in building up complex things from simple things he has not yet come near the artificial synthesis of proteids; (2) that we are at a loss to suggest what

in Nature's laboratory of chemical synthesis—a somewhat hypothetical witch's cauldron—could take the place of the directive chemist; and (3) that there is a great gap between making organic matter and making an organism.

The origin of organisms upon the earth remains a riddle, and the most that we can say is, that the hypothesis of the evolution of the living from the not-living is in harmony with the general trend of evolutionary theory. If it should become a tenable theory, the dignity and value of living creatures and of our own life would not be in any way affected. On the contrary, if the dust of the earth did naturally give rise to living creatures, if they are in a real sense born of her and the sunshine, then the whole world becomes more continuous and vital, and all the inorganic groaning and travailing becomes more intelligible.

We venture to quote in this connection a passage from Prof. Lloyd Morgan's *Interpretation of Nature*, which seems to us peculiarly useful in a little book like this. "It is true, and should be frankly admitted, that in the present state of natural knowledge the antecedent conditions of the genesis of protoplasm are unknown." . . . But, "those who would single out from among the multitudinous differentiations of an evolving universe this alone for special interposition would seem to do little honour to the Divinity they

profess to serve. Theodore Parker gave expression to a broader and more reverent theology when he said: 'The universe, broad and deep and high, is a handful of dust which God enchants. He is the mysterious magic which possesses'—not protoplasm merely, but—'the world'" (Lloyd Morgan, 1905, p. 77).

How did living creatures begin to be upon the earth? In point of Science, we do not know. We cherish the hypothesis, however, that living creatures evolved from not-living matter upon the Earth. We do so mainly because we do not know of any better hypothesis, and because it conforms with our (metaphysical) ideal of continuity and with the general idea of evolution. But we are aware that the hypothesis is beset with very serious scientific difficulties and with not less serious philosophical difficulties.

Consider, for a moment, a famous passage from Huxley: "If the fundamental proposition of evolution is true, namely, that the entire world, animate and inanimate, is the result of the mutual interaction, according to definite laws, of forces possessed by the molecules which made up the primitive nebulosity of the universe; then it is no less certain that the present actual world reposed potentially in the cosmic vapour, and that an intelligence, if great enough, could from his knowledge of the properties of the molecules

of that vapour have predicted the state of the fauna in Great Britain in 1888 with as much certitude as we say what will happen to the vapour of our breath on a cold day in winter."

This very strong and confident statement appears to us to illustrate the need for philosophical criticism. As Bergson points out, it denies that time really counts; it also denies that organisms are more than mechanisms. It denies the creative individuality of the organism, which trades with time in an unpredictable way all its own. It may be right in these denials, but the points are arguable. Moreover, the general idea of evolution does not warrant us in supposing that intelligent behaviour, for instance, "reposed potentially in the cosmic vapour" and could be predicted from a "knowledge of the properties of the molecules of that vapour"; for molecules and the like are abstractions of physical science which, for the purposes of that science, may be treated as if they represented the whole of the reality. The "primitive nebulosity of the universe" was a reality which, for the purposes of physical science, would be analysable into a whirling sea of molecules, but that certainly cannot have been the whole truth about it if in it there reposed potentially the present actual world. To take an analogy from development, there is no reason to believe that we should have exhausted

the reality of a human ovum if we knew all about the properties of its proteid molecules, nor that we could predict from that knowledge whether the ovum would develop into a genius or a fool.

THE SECRET OF THE ORGANISM.—One of the boundary-lines which is prominent in modern eyes is that between the inanimate and the animate, the not-living and the living. We call the bulk of things we see "purely physical"; we call a minority "physical *and* vital." We speak of this distinction as if it were self-evident, but we must not forget the panzoism of the savage and the child, the poet and the philosopher. To the former the distinction is unknown; by the latter it has been transcended. To simple people and to children, not-living bodies are often as alive as birds, and even the matter-of-fact man forgets his conventional philosophy on the golf-course and the curling-pond, commanding and upbraiding, encouraging and condemning, his ball or stone as if it were indeed a living creature. In spite of many resolute efforts on the part of philosophers and scientists alike—the boundary-line between the living and the not-living remains, and seems likely to remain for long. As it is of some importance in our outlook, let us consider this distinction between plants, animals and persons on the one hand and "mere things" on the other.

In the first place in regard to the inanimate,

the purely physical order: we almost always know what to expect from a stone; it is among the living that the unexpected happens. There is absolute uniformity of response in the physical order; there is caprice and humour in the animate order. We cannot recognize either individuality or purposiveness in inanimate systems. It is true that there is a great deal of effective work done in the purely physical order. The sea sculptures the shore, the river cuts a deep channel in the rock, the glacier wears the mountains smooth—but what is done is mechanically determined by the external conditions, not by any freely moving, purposive individuality. And while inanimate objects have a certain power of response to external stimuli, as the gunpowder shows when a lighted match is applied to it, the responses of a living creature in normal surroundings are of a higher order of efficiency, they make for self-preservation and betterment.

In discussing the characteristic features of living creatures in the volume on EVOLUTION, we have admitted that it is profitable to compare a living creature to a machine and a fertile method of discovery to press this comparison to its farthest. "Yet the living organism differs from any machine in its greater efficiency, and . . . in being a self-stoking, self-repairing, self-preservative, self-adjusting, self-increasing, self-reproducing engine!

And this also must be remembered in comparing a living creature with a machine, that the latter is no ordinary sample of the inorganic world. It is an elaborated tool, an extended hand, and has inside of it a human thought. It is because of *these* qualities that highly complex machines come to be so like organisms. But no machine profits by experience, nor trades with time as organisms do." Only living creatures have a persistent unified behaviour, a power of profiting by experience, and a creative capacity as genuine agents.

Here, then, we have one of the great contrasts in Nature, between the purely physical order and the world of organisms. The scientific question is whether the concepts and formulæ that suffice for the description of the inorganic world are also sufficient for the description of vital functions and animate behaviour. The answer of the mechanistic school is "Yes"; all others say "No," but not always for the same reasons.

We say "No" for the following reasons:—

(1) There are many chemical and physical operations in a living body, but as a matter of fact no complete physico-chemical description has yet been given of any distinctively vital activity. It has to be remembered that the most salient fact is the correlation and control of all the manifold chemical and physical processes so that a unified behaviour results.

(2) It is not a conclusive argument, perhaps, but one of some weight, that if we have not yet succeeded in giving a physico-chemical description of a simple vital process, such as the passage of digested food from the alimentary canal into the blood, or the filtering of the blood by the kidney, we need not at present seriously concern ourselves in regard to the possibility of giving a physico-chemical description of growth, cyclical development, or every-day behaviour. If we think of development for a moment, we cannot but feel that the questions which the facts raise seem *very unlikely* to receive an answer in terms of mechanism. How are the heritable characters of the race summed up potentially within the minute germ cells? How do they gradually find expression in the individual development, so that what we call differentiation results? What is the nature of the compelling necessity that mints and coins the chick out of a drop of living matter? What is it that regulates the ordered progress which, by intricate and often strangely circuitous paths, leads to the fully-formed organism? It is certainly wonderful the individual unpacking of the racial treasure-box!

(3) But the most satisfactory reason, perhaps, is the one referred to in the chapter on Scientific Method, that the results of applying physico-chemical analysis to the activities of living crea-

tures do not make these much more intelligible. They do not give us the kind of answer that we want in our endeavour to understand these creatures better. Their development, their behaviour, and the correlation of their internal activities, cannot be understood except on the assumption that they are historical beings—as Bergson has so well insisted.

Here the scientific position, all too briefly indicated, ends; but it is open to the philosopher to go farther. All that we have said is that the mechanistic formulation of living creatures does not answer the distinctively biological questions, but for some minds it is imperative to go farther. Where Science ends Philosophy begins; and in Dr. Hans Driesch's *Science and Philosophy of the Organism* we have one of the finest recent illustrations of a welcome partnership of the two disciplines. We need not attempt to discuss his strenuously thought-out theory of Vitalism, the point for us here is simply that after giving three scientific proofs that the mechanistic theory will not work, he goes on to a philosophical construction—the conception of the "Entelechy"—an immaterial autonomous factor which punctuates the transformations of energy that go on within the body. The "Entelechy" is the living creature's innermost secret, its directive soul, and whether Dr. Driesch has been successful or not, he has

certainly been extraordinarily ingenious in evading the old criticism of crude views that the insinuated immaterial factor, if it is to be effective, must invalidate physico-chemical laws.

As an appendix to this brief discussion, we wish to refer to the very strongly expressed conclusions of the most distinguished physicist of the age—Lord Kelvin. He was, indeed, no biologist, but the opinions held by one of his intellectual eminence claim our attention. He knew how far his Physics could go.

"The only contribution of dynamics to theoretical biology is absolute negation of automatic commencement or automatic maintenance of life."

"The opening of a bud, the growth of a leaf, the astonishing development of beauty in a flower, involve physical operations which completed chemical science would leave as far beyond our comprehension as the differences between lead and iron, between water and carbonic acid, between gravitation and magnetism, are at present. A tree contains more mystery of creative power than the sun, from which all its mechanical energy is borrowed. An earth without life, a sun, and countless stars, contain less wonder than that grain of mignonette."

An Illustration.—Let us select some instance of animal behaviour and look at it from the mechanist and vitalist point of view. We take a

vivid one—the Migration of Eels, which has been recently discussed in this connection by Mr. E. S. Russell ("Vitalism," *Rivista di Scienza*, April, 1911). It is a useful case, because the animal has a brain of a very low order, and we are not warranted in using in regard to it the psychological terms which are indispensable in the case of the more intelligent birds and mammals.

The eels of the whole of northern Europe probably begin their life below the 500-fathom line on the verge of the Deep Sea away to the west of Ireland and southward—*on the verge* of the dark, cold, calm, silent, plantless world of the abysses. The young eel develops and starts in life, and feeds and grows far below the surface, but the early chapters of the life-history are still quite obscure, and do not at present concern us. It rises to the upper sunlit waters as a transparent, sideways flattened, knife-blade-like larva, about three inches in length, with no spot of colour except in its eyes. It lives for many months in this state—known as a *Leptocephalus*—expending energy in gentle swimming, but taking no food. It subsists on itself, and becomes shorter and lighter, and cylindrical instead of flat. It is gradually transformed into a glass-eel, about two and a half inches long, like a knitting-needle in girth. It moves towards the shores. After about a year it is one of a million elvers passing up one

of our rivers—in the wonderful eel-fare which is one of the sights of Spring. If it is not fortunate, it may take much more than a year to reach the feeding-ground—those that ascend the rivers of the eastern Baltic have journeyed over three thousand miles. Eventually, however, a large number do pass up the streams, and there is a long period of feeding and growing in the slow-flowing reaches and in fish-stocked ponds. There is never any breeding in fresh water, but after some years restlessness seizes the adults as it seized the larvæ—a restlessness due to a reproductive, not a nutritive motive. There is an excited return journey to the sea—and they don wedding garments of silver as they go, and become large of eye. They appear to migrate hundreds of miles, often out into the Atlantic to the verge of the Deep Sea, where, as far as we know, the individual life ends in giving rise to new lives. In no case is there any return.

We ask then what the Machine theory of Life can make of a story like this, and it is only a type of many. Let us keep to the second last chapter, the migration to the spawning-grounds. Like many other fishes, the eel requires specific conditions of depth, salinity, and temperature. The North Sea will not serve, for it is too shallow; the Norwegian will not serve, for it is too cold.

What can the physiology that is only applied

physics and chemistry tell us? It can tell us how the energy for the journey is obtained from chemical explosions of reserve material in the muscles of the eel's tail. It can tell us some of the steps in the making of these reserve materials out of the eel's food. It can tell us that the muscles are kept rhythmically contracting by nervous stimuli, and so on for a whole volume, and yet it does not help us to understand the migration to the spawning-grounds. To take items in the process and reduce them (as far as possible) to physical and chemical common denominators, does not make any clearer the inter-connection of all these items into the single act of migration. Apply physico-chemical methods by all means, the results are always of interest, but the results are not *useful* in making the biological fact of migration more intelligible.

Let us linger over the illustration, for it is very instructive. As Russell says: "The migration is, so to speak, a fact of a higher order than any physical or chemical fact, although it is made up of an indefinitely large number of physical and chemical facts. To explain the fact one must accept it as a whole, not seek to conquer it by dividing it, for if one analyses it into its components one inevitably misses the bond of union. . . . To decompose the act of migration into an infinity of physico-chemical processes is to take

an infinity of little partial views of the act, but what one needs for an explanation of the fact is a comprehensive view which will unite all the relevant features of it into one picture. To the chemist confronted with this problem there is no fact of migration at all, there is only an intricate enravelment of chemical reaction; to the biologist the fact of migration to a particular region for a particular purpose is cardinal, and the chemical processes involved in the action are negligible."

But if the mechanistic account of the eel's migration fails, is the vitalistic one any better? Let us think of this for a little. The aim of biology is not to give ultimate explanations, but to render biological phenomena intelligible; and that means to obtain general conceptions as to their nature. We explain a thing biologically when we relate it to some general fact or formula of living things.

Therefore if pressed to make the story of the eel less of a curiosity, we should ask to be allowed to start with the concept of an organism with certain at present irreducible qualities—one of the biggest of which is simply that it is an historical being. It is determined by the past—its own past and the past of its race. Its inheritance is a treasure-store of the ages. Non-living things have no history in the biological sense. The

hand of the past has left its impress on them, but the living hand of the past is on the organism for ever. In the organism, as Bergson says, the past is prolonged into the present. Thus we pass on to a new level of explanation or interpretation —which is historical.

And whenever we mention that the eel is one of a deep-sea race which has adventurously taken to colonizing the fresh waters—just as the salmon is one of a freshwater race which has taken to exploiting the sea, and notice further that animals in general return to their birthplace to breed—then at once a biological light begins to be shed on the eel's strange story.

The "Soul and Body" Problem.—No one understands how living creatures began to be in pre-Cambrian ages in a lifeless world, and no one understands the innermost secret of their activity. Similarly at a higher level: No one understands how thinking creatures began to be, nor understands what the innermost secret of thinking is. But just as the scientific inquirer has a contribution to make to the discussion of the origin of life and the autonomy of the organism, so he has something to say in regard to the perennial question of the relation between body and mind, a question which is, however, essentially metaphysical.

The scientific contribution is threefold:—

(*a*) In the first place, while we do not know of any transitions between the not-living and the living, we have a long inclined plane or a long series of steps connecting the very simple reactions of unicellular creatures with the intelligent behaviour of dogs and horses, and even with the rational conduct of man. This inclined plane or this staircase is very impressive, and must have a bearing on the general problem. There is a fascination in what may be called the beginnings of behaviour, illustrated by some of the Infusorians. Their daily life seems as if it could be summed up in a sentence. They have only one answer to every question. To all sorts of stimuli they respond in the same way—by backing off, turning slightly on one side, and then going ahead again. They remind us of a steamer in a river which knocks against a snag, reverses engines, alters its direction a little, and then steams ahead. This is surely the simplest kind of behaviour, where there is only one reaction.

Slightly higher in the scale, but still very simple, is the behaviour of some Protozoa which have a number of reactions or responses to stimuli, and seem to try one after the other until, it may be, one succeeds. We do not know how much lies concealed in that process of "seeming to try." We know that it is different from the experimenting of a scientist who tries various ways of solving

a problem; we know that it is different from the experimenting of a burglar who tries which key in a bunch will open a particular door; we know that it is different from the experimenting of a dog trying to take a stick with a hooked handle through the close-set upright bars of a fence; we know that it is different from the behaviour of earthworms trying various ways of transporting leaves to their burrows; but is it not the *beginning* of the "trial by error" method, common to all these instances?

(*b*) In the second place, the "genetic psychologist" has much to tell us of the individual development of behaviour, of the gradual emergence of capacities of action—whether instinctive (involving apparently no inference), intelligent (involving apparently perceptual inference), or rational (involving conceptual inference). Comparative child-study in the wide sense, zoological as well as anthropological, has surely some bearing on the general question.

(*c*) In the third place, Science has much to say in regard to the actual correlation between the static and the dynamic aspects, between structure and function. Complexity of brain structure is associated with very intelligent behaviour; increase in the complexity of brain structure from year to year in the individual is associated with increased capacity of intelligent

behaviour; certain parts of the brain are correlated with certain kinds of behaviour such as speech; the health or the disease of the brain is correlated with the efficiency of behaviour. There are numerous scientific data of this sort, and they have nothing particular to do with the metaphysical theory of "psycho-physical parallelism."

The scientific inquirer tries to fight shy of the metaphysical problem of the relation of body and mind, but, of course, in vain. He will hold to the unity of the organism (thus making a metaphysical assumption), and it is the behaviour of the creature that he will particularly study. He can watch the dog and describe its behaviour; he can make experiments to test its alertness, its memory, its power of inference, and so on. In the case of birds, whose eggs can be hatched in the laboratory, he discovers what capacities are inborn and what have to be acquired by learning. He can do all this without getting into difficulties over the relations of the dog's body and the dog's mind. The biologist prefers to keep to the dog. In this practical monism he is confirmed by the philosophers who make it clear that "body" and "soul" are equally abstractions. "The severance of the original unity of experience into a physical and a psychical aspect is entirely a product of our own

abstraction-making intellect. 'Body' and 'soul' are not given actualities of experience, but artificial mental constructions of our own" (Taylor, 1903, p. 314). We are the realities, who pigeonhole for purposes of study our "mind" and our "body."

The scientific inquirer may try to remain as a student of "the original unity of his experience," agnostically confronting one of the great mysteries of the world, but as a man he soon strains at his self-made tether. And he is likely to be soon back at the old questions: Which is primary—the Brain or the Mind? Is the brain the instrument or means, rather than the condition or cause, of mental development? Do the bodily changes form an unbroken causal series, sometimes associated with states of consciousness, which are effects, but never causes? Or is there a curious double series of cerebral events and psychical events, running "parallel" (whatever that may mean) but not causally connected? Or are there two series of processes going on which interact, causally influencing one another at different points, sensation being a mental state which has bodily processes (in the nervous stimulation) among its immediate antecedents, and a motor reaction similarly a bodily process with mental antecedents (our will)? We need not go farther: the scientific inquirer has landed in the

discussion of the metaphysical theories of "epiphenomenalism," "parallelism" and "interaction."

Apart from frankly metaphysical speculation, the possibilities are (1) to remain content with an agnostic position, or (2) to push on the scientific study yet farther.

(1) We may illustrate the first possibility by a quotation from Huxley (1863): "I must adhere to what seems to my mind a simpler form of notation—*i. e.* to suppose that all phenomena have the same substratum (if they have any), and that soul and body, or mental and physical phenomena, are merely diverse manifestations of that hypothetical substratum. In this way, it seems to me, I obey the rule which works so well in practice, of always making the simplest possible suppositions." . . . "My fundamental axiom of speculative philosophy is that *materialism and spiritualism are opposite poles of the same absurdity*—the absurdity of imagining that we know anything about either spirit or matter" (Huxley, 1863).

(2) We may illustrate the second possibility by a quotation from Prof. W. MacDougall: "We observe a constant concurrence or concomitance of events of the two orders—the physical and the psychical; and this constant concomitance leads even the most unreflecting man to assume some orderly relation between them. The fact of the

relation has therefore always been recognized since men first began to reflect. But the nature of this relation that so clearly obtains between the physical and psychical worlds remained a subject of speculation only until long after the scientific method has been applied with success to each of these realms independently. In fact, it was not until the middle of the nineteenth century that the scientific method was brought to bear upon the problem of the nature of this relation; and it was this, the application of the scientific method to this problem, that led to the development of that youngest branch of science known as psycho-physics.

"For psycho-physics may be broadly defined as the application of the scientific method to the investigation of the relation between the psychical and the physical. This step was taken, and this new branch of Science was founded, by Gustav Theodor Fechner, Professor of Physics at Leipzig, with full consciousness of the nature and importance of the step. In his celebrated work, *Elemente der Psycho-physik*, published in 1860, Fechner says: 'By psycho-physics is to be understood an exact study of the functional relations, or relations of dependence, between body and soul, or, in more general terms, between the bodily and the mental, the physical and the psychical worlds." (See MacDougall: "Psycho-

physical Method," in *Lectures on the Method of Science*, Oxford, 1906, p. 114.)

A QUESTION.—In regard to "the soul and body problem" and also in regard to "the secret of the organism," some reader may be inclined to press the following question: This discussion of "the unity of the organism" and "the autonomy of the organism" is all very well, but do you mean that there is in the living creature more than matter and energy, or not? To this and similar questions the scientific answer must be that the question is not rightly put. We do not know what matter really is, nor what all the energies of matter may be. What we do know is, that physico-chemical formulæ do not make the living creature intelligible, and that we have no warrant for asserting that the physical concepts of "matter" and "energy," abstracted off for special scientific purposes, exhaust the reality of Nature.

We have known of a school where the distinctive feature was solidarity, loyalty, and *esprit de corps*. No one ever saw this *esprit de corps*, but it was, in a way, the most real thing about the school. So, though we may not be able to understand it, the hierarchy of Nature is full of illustrations, on an ever grander scale as we ascend the series, of the fact that the whole may be greater than the sum of its parts. Thus we

feel sure that organisms reveal a deeper aspect of reality than crystals do, and that in this sense there is more in the plant than in the crystal, more in the animal than in the plant, more in the bird than in the worm, more in man than in them all.

Let us try to state our personal position in a few words. With our biological prepossessions it seems clear to us that students of science would breathe more freely if they could rid themselves of the influence of the hypothesis, so characteristic of Kant, that there is but one science of Nature and that the category of mechanism is the only one we need. It seems to us that there are *several* sciences of Nature, and that other than mechanical categories are required in two of these.

(1) There is the physical order of Nature—the inorganic world—where mechanism reigns supreme. (2) There is the *vital* order of Nature—the world of organisms—where mechanism proves insufficient. (3) There is the *psychical* order of Nature—the world of mind—where mechanism is irrelevant. Thus there are three fundamental sciences—Physics, Biology, and Psychology—each with characteristic questions, categories and formulæ.

It is evident, indeed, that the physical order overlaps the vital, for the life of the organism

implies a succession of chemical and physical processes. But, as we have seen, the life of the organism also implies a co-ordination, a purposiveness, an individuality, a creative agency, a power of trading with time, a history—in all of which it transcends mechanism. Similarly, both the vital and the physical overlap the psychical without, as we understand it, affecting the autonomy of psychology.

Looking at the question historically, we recognize that there was for millions of years, in the development of the earth, only a physical order as far as met the eye. That is to say, everything (short of the origin of life) that happened during these millions of years was capable of description in physico-chemical terms. These are so "true to Nature" that just as we can predict the return of a comet, so in many cases we can safely speak of great events that occurred before there was any life whatever upon the earth. It is quite another matter, however, to say that physico-chemical categories *exhausted* the reality of Nature in these pre-organic days. Indeed, if life and mind and man have evolved from the reality which was physically describable as a nebula, we may safely say that the physical description is certainly not exhaustive.

In the same way, there were long ages, in the evolution of organisms, during which (in addi-

tion to the physical) there was only a vital order. No brains worthy of the name had yet been differentiated, and everything might have been described in biological terms, just as we may describe the ongoings of an amœba or of a fresh-water hydra. It is quite another matter, however, to say that biological categories exhausted the reality of animate Nature in these pre-mental days. Indeed, if intelligent behaviour and human reason evolved from the reality which was biologically describable as a number of simple organisms, we may safely say that the biological description is certainly not exhaustive. The same holds good in regard to the development of the individual human being.

In questions like this, which are perhaps beyond the limits of human intelligence, diagrams and metaphors are apt to do more harm than good, but we might compare the order of Nature which we study to a great fabric passing from the loom of time with a pattern slowly changing as the ages pass. It is woven of threads of different colours which it is the business of the several sciences to follow, unravelling the web. We can well imagine that there are areas of fabric in which certain threads seem to be absent, where, indeed, their hidden presence may be ignored, *except in reference to further stretches of the web.* In the area that we call the physical order we

can afford to act as if the only threads were mechanical, but in truth it may be otherwise. In the area which we call the biological order the mechanical threads are continued, but they are no longer dominant. In the area which we call psychical the organic threads are continued, but others form the pattern. As we pass from inorganic to organic, from organic to psychical, the mechanical warp becomes as it were less important, and new aspects of Reality find freer expression. But the metaphor is hopeless in its suggestion of threads that are passively twisted and interlaced. We have to think of living threads, like those of some of the simplest Protists which spin a changeful web. We have to think of living threads that share in working out the pattern of the web.

Summary.—*The aim of Science is the description of facts, the aim of Philosophy their interpretation. There is much need for critical Metaphysics to function as a sublime Logic, testing the completeness and consistency of scientific descriptions, whether of things as they are or of the way in which they have come to be. On the other hand, metaphysics should not reach forward to its constructive system without taking account of the raw material which the sciences furnish. The scientific account of things is self-limited by the nature of its descriptions: Only in mechanics can we say "The Cause*

is equal to the Effect," the terms of scientific description require themselves to be explained; the beginnings from which Science starts contain much that is "given" or taken for granted; the terms of scientific descriptions are "conceptual formulæ." Before problems such as the origin of living creatures upon the earth, the secret of the organism, the relation of soul and body, Science and Philosophy must meet. Science offers certain contributions to the discussion and must then remain qua *Science agnostic. To most minds it seems imperative to go on to metaphysical theory, and it is better to do this frankly and deliberately than unconsciously or at random.*

CHAPTER VI

SCIENCE AND ART

"For double the vision my eyes do see,
And a double vision is always with me:
With my inward eye 'tis an old man grey,
With my outward a thistle across my way."

—BLAKE.

Inter-relations of Science and Art—Æsthetics—Man's Emotional Relation to Nature—Fundamental Impressions of Nature—Nature more than a Mirror—Raw Materials of Poetry—Opposition between Science and Feeling—Summary.

INTER-RELATIONS OF SCIENCE AND ART.—The connection of the Sciences with the arts and crafts is well known, but it is generally supposed that Science and Art (both with very large capitals) are as the poles asunder. And this in spite of the "Science and Art" Department and its examinations, so familiar thirty years ago!

Of a truth, however, the ideal which these expressed, perhaps not always wisely or well, was a sound one, for Science and Art have close relations. In the first place, there is a scientific

study of æsthetics, a psychology of Art—a subject so difficult that we cannot do more than refer to it here. In the second place, it is certain, though rarely realized, that Science has precious gifts to place in the hands of Art that she may fashion them magically into beauty. Science has enormous treasure-caves full of what we cannot but describe as the raw materials of poetry. And just as the famous painter told his questioner that he mixed his colours "with brains," so it is beyond doubt that Science, with its subtle revelations of the order of Nature, may enhance even the artist's visions. In the third place, in spite of what we have just said, there is a very interesting opposition between the two moods. They may help one another, but when one is in the saddle it must keep the other at a spear's length.

There is another possible relation between Science and Art which well deserves to be thought over. Is it not the case that in its higher reaches Science often becomes artistic? Thus Mr. Branford writes—

"Routine-skill, scientific skill, and artistic skill form an ascending series of human power and activity. For true art, in whatever occupation it may be developed, is the final and highest expression of our whole character, powers, and personality—whether the artist be a handicraftsman or a headcraftsman, or both. Above and

beyond their scientific skill, all great scientists possess much of this artistic skill, the very portion, indeed, of their experience and experimenting which they themselves never fully understand, though the source of their greatest discoveries, and which, essentially incommunicable, necessarily dies with the possessor" (Branford, 1904, p. 12).

ÆSTHETICS.—As we have indicated, it is beyond our power in this short Introduction to do more than refer to the interesting study called æsthetics. It inquires into the characteristics of that familiar experience which we call enjoying Nature or Art, and of the rarer experience of productive artists. It asks such questions as the following: How does the sense of beauty differ from other states? The pleasure that we get from music or from the silence that is in the starry sky, from the restless sea eternally new or from the sleep that is among the lonely hills; how does it differ from other pleasures? What is the meaning of those sensations that follow changes in breathing, circulation, and the like, when we enjoy beautiful scenery and music? What gives æsthetic pleasure its peculiar quality of "relative permanency," a thing of beauty being "a joy for ever" though we never see it again? What can be known of the "artistic instinct" or of the artist's creativeness? How is the art-instinct linked to the play-instinct?

What have been the factors in the evolution of Art?

It goes without saying that æsthetics has its philosophical as well as its scientific side, and we may perhaps best illustrate the former in a brief space by quoting the views of a leading æsthetician on the relations of the True and the Good and the Beautiful. Dr. Henry Rutgers Marshall suggests that "the Beautiful is the Real as discovered in the world of impression; the relatively permanent pleasure which gives us the sense of beauty being the most stable characteristic of those parts of the field of impression which interest us." He proposes the following scheme—

THE REAL or THE TRUE (in the broad sense of the term).	α. The Real of Impression—The Beautiful. β. The Real of Expression—The Good γ. The Real in Realms exclusive of α and β—The True (in the narrower sense of the term).

MAN'S EMOTIONAL RELATION TO NATURE.—It is part of "man's chief end" not only to know Nature—which is Science, but to enjoy her for ever. We are men of feeling, and Nature speaks to our heart, though we are not fond, unless we

are poets, of saying much about it. But we listen with gladness, with awe, sometimes, perhaps, with fear, surely always with wonder. The grandeur of the star-strewn sky, the mystery of the mountains, the sea eternally new, the way of the eagle in the air, the meanest flower that blows —somewhere, sometime, somehow, every one confesses with emotion, "This is too wonderful for me." When we consider the abundance of power in the world, the immensities, the intricacy and vitality of everything, the wealth of sentient life, the order that persists amid incessant change, the vibrating web of inter-relations, the thousand and one fitnesses, the evolutionary progress that is like "the unity of an onward advancing melody," and the beauty that is through and through, we are convinced that our wonder is reasonable.

As we come to know Nature better, we find that everything is equally wonderful if we know enough about it, for, as Meredith says, with his wonted insight: "You of any well that springs, may unfold the heaven of things." As Whitman says—

> "A leaf of grass is no less than the journey-work of the stars,
> And the ant is equally perfect, and the grain of sand, and the egg of the wren,

And the tree-toad is a masterpiece for the highest,
And the running blackberry would adorn the parlours of heaven,
And the narrowest hinge on my hand puts to scorn all machinery,
And the cow crunching with depressed head surpasses any statue,
And a mouse is miracle enough to stagger sextillions of infidels."

As we begin to feel at home in Nature, our wonder grows into delight and what may almost be called affection. This is true of those who have what Meredith called "love exceeding a simple love of the things that glide in grasses and rubble of woody wreck." In many ways we are drawn close to Nature by emotional cords which we sever at our peril.

Historical inquiry shows that in the culture of the mood which dominates the man of feeling there have been two great schools—human life itself and Nature. It is evident that without schooling in the human drama, with its joys and sorrows, achievements and failures, Man would have made much less of Nature emotionally. One may go farther and say that without age-long schooling in the Humanities, Man would have made much less of Nature. On the other

hand, from the first till to-day schooling in Nature has deepened humane feeling, as many of the poets have confessed; and our position is that schooling in Nature has been and remains an essential part of the discipline of the developing human spirit. Think of the past for a moment.

Man was cradled in Nature and brought up in close contact with Nature, and the influences of Nature have supplied the raw materials of, perhaps, half the poetry and art in the world. From language and literature, from religion and rites, and from what may be seen still among simple peoples, it seems certain that the influences of Nature took a very firm grip of Man in the making. Very largely, perhaps, in a half-conscious way, just as in our own childhood, but none the less firmly. The poet tells us of the child who went forth every day, and what the child saw became part of him for a day, or for years, or for stretching cycles of years; and what is true of the individual has been equally true of the race.

Fundamental Impressions of Nature.—It is unlikely that the impressions borne in on our early ancestors were essentially different from those that come to us, though the particular form and colour of the impression must vary from age to age. What, then, are the essential impressions? When we reflect on this in the

silence of a starry night, or in the bewilderment of a storm, or in the detachment of mid-ocean, or with the exalted feeling that rewards a long climb, we recognize various elements which combine in the complex feeling of Wonder.

First, there comes to us a sense of the world-power, its dynamic—a sense of the powers that make our whole solar system travel in space toward an unknown goal, that keep our earth together and whirling round the sun, that sway the tides and rule the winds, that mould the dew-drop and build the crystal, that clothe the lily and give us energy for every movement and every thought—in short, that keep the whole system of things agoing. Looking at radium-containing rock and the like with modern spectacles, we get a glimpse of the powers—like charmed genii—that may be imprisoned in the apparently inert dust. Even more vividly to some of us there comes a sense of the power of life—so abundant, so insurgent, so creative. "The narrowest hinge on my hand puts to scorn all machinery"; a fire-fly is a much more economical light-producer than an arc-lamp; a fish is a far more efficient engine than those which move a steamship; and an invisible pinch of microbes could kill all of us in a few hours.

Secondly, there comes to us a feeling of the immensities. It was a red-letter day in our child-

hood when we first climbed to the summit and saw over the hills and far away—strath beyond strath, and then the sea; and the simple, open mind has always been impressed with the "bigness" of Nature, with the apparently boundless and unfathomable sea, by the apparently unending plains, by the mountains whose tops are lost in the clouds, by the expanse of the heavens. And even when we take the sternest modern science for our pilot—precise and cautious to a degree—we find that we are sailing in a practically infinite ocean. For leagues and leagues beyond there is always more sea.

Thirdly, there comes a sense of pervading order. Probably this began at the very dawn of human reason—when man first discovered the year with its magnificent object-lesson of regularly recurrent sequences, and it has been growing ever since. Doubtless the early forms that this perception of order took referred to somewhat obvious uniformities; but is there any essential difference between realizing the orderliness of moons and tides, of seasons and migrations, and discovering Bode's law of the relations of the planets, or Mendeleeff's "Periodic Law" of the relations of the atomic weights of the chemical elements?

Fourthly, there comes to us a feeling of the universal flux, in spite of which order persists. As Heraclitus said, πάντα ῥεῖ, all things are in

flux. "The rain falls; the springs are fed; the streams are filled and flow to the sea; the mist rises from the deep and the clouds are formed, which break again on the mountain side. The plant captures air, water, and salts, and, with the sun's aid, builds them up by vital alchemy into the bread of life, incorporating this into itself. The animal eats the plant; and a new incarnation begins. All flesh *is* grass. The animal becomes part of another animal, and the reincarnation continues." Finally, if we can use such a word, the silver cord of the bundle of life is loosed, and earth returns to earth. The microbes of decay break down the dead, and there is a return to air and water and salts. All things flow. It may be that the old naturalists had not such a vivid conception of the circulation of matter as we have to-day, but the essential idea is certainly ancient.

Perhaps we have said enough to illustrate this part of our simple argument (which we have developed further in *The Bible of Nature*, 1908) that there are certain inevitable and fundamental impressions borne in on man by Nature which have meant much to man throughout the ages, which are strengthened, not weakened, by modern science. They have not changed in their essential character since ancient days, but they have become deeper and more subtle—the impressions

of power, of immensity, of order, and of flux. These are probably the most widespread and fundamental impressions, but every open-eyed observer to-day has doubtless others that have meant much to him in the way both of stimulus and of mental furniture.

There is the impression of wealth, exuberance, and manifoldness. Star differs from star in glory and their numbers are beyond reckoning; every mountain, every stream, has its individuality; there are over eighty different kinds of chemical elements; the number of minerals is legion; there are four hundred and forty-two species of birds in the list for the small islands of Great Britain and Ireland; and there is many a class of animals that has far more different species than we see of stars on a clear night.

An allied impression is that of intricacy. As President Jordan says, "The simplest organism we know is far more complex than the constitution of the United States." The body of an ant is many times more intricate—visibly intricate—than a steam-engine; its brain, as Darwin said, is perhaps the most marvellous speck of matter in the universe. The physicists tell us that the behaviour of hydrogen gas makes it necessary to suppose that an atom of it must have a constitution as complex as a constellation, with about eight hundred separate corpuscles.

Another impression of a basal sort is that the world is a network of inter-relations. Nature is a vast system of linkages. There is a correlation of organisms in Nature comparable to the correlation of organs in our body. There is a web of life. Cats are connected with the clover crop, rats with plague, earthworms with our food-supply, the spring sunshine with mackerel. The face of Nature is like the surface of a gently flowing stream, where hundreds of dimpling circles touch and influence one another in an intricate complexity of action and reaction beyond the ken of the wisest.

These impressions of manifoldness, of intricacy, of inter-relatedness are relatively modern, as is also a sense of the crowning wonder of the world, that the succession of events has been in the main progressive. What we more or less dimly discern in the long past is not like the succession of patterns in a kaleidoscope; it is rather like the sequence of stages in the individual development of a plant or an animal—stages whose import is disclosed more and more fully as the development goes on. It is not a phantasmagoric procession that the history of animate Nature revels: it is a drama. As Lotze said, there is "the unity of an onward-advancing melody."

NATURE MORE THAN A MIRROR.—We are

seeking to suggest that there are a number of strong impressions borne in on man by Nature which have formed and should continue to form the raw materials of poetry and the impulses of other forms of art. But before continuing this simple argument, we must pause for a moment to protest against the not uncommon heresy that Nature is man's creation! We are told that Nature has no suggestions of her own, that what we see in Nature depends on the arts that have already influenced us, that Wordsworth found in stones the sermons which he had himself hidden there.

But this seems to us an extreme subjectivism. It is indeed the function of Art to read into Nature, but the impressions which we have been discussing have scientific validity. And if it be urged that it is difficult to free even science from anthropomorphism, as has been illustrated in the volume on EVOLUTION in this Library, we should answer that this applies rather to theoretical interpretations than to the great data of experience. When a scientific impression is really sound, it is not something that may be accepted or rejected as one will, it does not depend on individual outlook, it stands the test of verifiability by all normal intelligences.

RAW MATERIALS OF POETRY.—Our argument, then, is this, that the fundamental impressions

of Nature, some of which we have indicated, have scientific validity. They are borne in on man and not artistically projected from him. They are cumulative syntheses of facts of experience, and some of them, though varying in form and colour from age to age, are very ancient. They have never ceased to supply the raw materials of poetry. Demonstrably, indeed, a large part of the world's poetry from Homer to Tennyson, from the Nature-Psalms to Meredith, has been saturated with their influence.

In ancient days there were those who knew Nature well and loved her well, who felt that while they could discover certain secrets that cleared their outlook and made for practical advantage, yet there remained much that was elusive and mysterious. So they did what Man has always done, they used art to express their feeling of Nature's powers and immensities, of the pervading order amid a restless flux. For instance, they fashioned what we sometimes call Fairy Tales, many of which are *artistic expressions of very sound science.* Many of them, for instance, reveal a very penetrating insight into the gist of natural phenomena, especially of the march of the seasons. Let us take one instance.

"There was Dornröschen, the Sleeping Beauty —(our fair Earth), wounded by a spindle (the

frost of winter), who slumbered, as the seeds do, but did not die. One after another strove, so the story runs, to win a way through the barriers which encircled the place of her sleeping, but at length the Prince and Master came, to whom all was easy—the Sunshine of the first spring day; and as he kissed the Sleeping Beauty, all the buglers blew, both high and low, the cawing rooks on the trees, and the croaking frogs by the pond, each according to his strength and skill. All through the palace there was reawakening: of the men-at-arms, whether bears or hedgehogs; of the night watchmen, known to us as bats; even of the carpet sweepers, like dormice and hamsters —all were reawakened. The messengers went forth with the news, the dragon-flies like living flashes of light, the bustling humble-bees refreshing themselves at the willow catkins by the way, the moths flying softly by night."

If these are not good interpretations, there are other exegeses to choose from. (See Frazer's *Golden Bough* and our *Biology of the Seasons*, 1911.)

Fine as are the old Nature myths and fairy tales, it seems obvious that each age should make its own, if it can. And the possibility depends on two things. *First*, on keeping close to the fundamentals, sojourning with Nature, for it is touching and handling that counts; listening to sounds,

not to echoes of sounds; experiencing day and night, summer and winter, cold and heat, not simply reading about them. "*Nur was du fühlst, das ist dein Eigenthum.*" "Only what you feel is your very own." And *second*, on enriching the mind with the results of science, with its fresh facts, its new outlooks, its revised laws. Only thus may there arise a new Nature-poesy—a new heaven and a new earth such as each generation has a right to make for itself.

What an emotional asset, for instance, in the facts regarding the Earth's relation to the Sun which is its "mother-country"! "All energy is a transformation of the sun, the logs which feed our hearths are warehoused from the sun, the locomotive moves by an effect due to that power of the sun which has been lying dormant for ages in the subterreanean beds of coal, the horse draws its strength from crops which are also produced by the sun," and so the familiar story runs to water-mills and windmills and how much more—all owing their power to the sun.

The emotional assets furnished by astronomy are well known. They are so great that we can well understand the poet's conviction that "the undevout astronomer is mad." We have referred to the immensities of Nature, but better than big words is the picture in the volume on ASTRONOMY in this Library. "Imagine a model in which the

sun is represented by a grain of sand one-hundredth of an inch in diameter, and the earth by a quite invisible speck one inch away. Upon this scale the nearest star will be another grain of sand some four miles away." . . . The sun would take at his present speed in space some seventy thousand years to reach his nearest neighbour. . . . "Despite the richness of the sky, the emptiness of space is its most striking characteristic."

The great concepts of physics—such as the law of gravitation, the luminiferous ether, and the conservation of energy—are assets in the life of feeling. "In accordance with the conception of the conservation of energy there is no real cessation of energy motion, there is only an alteration in its mode; thus the sum total remains for ever the same, one mode changing to another without any energy ceasing or being lost in the transformation." And speaking of this, Prof. Gotch continues: "Such an imaginative flight is far beyond all sense experience. To the thought of a scientific man the universe, with all its suns and worlds, is throughout one seething welter of modes of motion, playing in space, playing in the ether, playing in all existing matter, playing in all living things, playing, therefore, in ourselves. Now locked together in more intimate embrace, potential energy, now unlocked and streaming as

kinetic energy through space, continually alternating between these two settings, this eternal motion never ceases, is never dissipated, and is never recreated; it simply exists. The conception thrills the imagination like a poem" (Gotch, 1906, p. 55).

One of the great changes in modern intellectual development has been the transition from a static to a dynamic way of looking at things. What began in astronomy spread to geology and thence to biology, and now every science owns to the change. The subject-matter is considered in its becoming, in its present activity, and as in process of evolution. Everything is seen "in the light of evolution." And this familiar intellectual transition has given a thrill to art.

Again, it is well known that modern progress in chemistry and physics has given us a much more vital conception of what has been labelled or libelled as "dead matter." To speak of *inert* matter, at any rate, is an anachronism. We believe that every one who feels something of the witchery and mystery of precious stones will admit that his vision is illumined and intensified by what modern science has to tell of the internal activity or "life" of jewels.

And, again, it is characteristic of at least a large school of modern biologists that they assert the autonomy of their science and the transcen-

dence of life over mechanism. We cannot give a mechanical interpretation of an animate system that in some mysterious way is more than the sum of its parts, that has unified effective behaviour from the start, that has experience and profits by it, that has a history behind it and never ceases itself to trade with time. Thus the Neo-Vitalists have made a home for the Dryad, which some of them think they have even demonstrated. With a suitable constituency of serious students, the severer the biological discipline is the more vital do things become. The old woodman who planted and tended his tree often had an almost personal or parental interest in his charge; the modern forester may lose this with the change in the world's pace, but there comes to him instead, in proportion as he knows his business, a vision of the tree translucent, with its intricate architecture and its intense life. "The Dryad, living and breathing, moving and sensitive, is again within the tree."

Let us collect a few Natural History illustrations. Many voyagers across the Atlantic have watched the sun set in the water, lingering for a minute or two like a ball of fire balanced on the tight string of the horizon, and have waited afterwards till it was quite dark except for the stars and the "phosphoresence"—a multitude of glowing suns above and a greater multitude of gleam-

ing animalcules below! There is a cascade of sparks at the prow, a stream of sparks all along the water level, a welter of sparks in the wake, and even where the waves break there is fire. So it goes on for miles and hours—the luminescence of the rapid burning away of pinhead-like creatures, so numerous that a tubful contains more of them than there are people in London and New York together. This is just one of a thousand ways of feeling *the abundance of life.*

Many have enjoyed one of the great pleasures in life, that of crossing an Alpine pass of moderate height, where we get near the lasting snows and are among the bare, inhospitable rocks. There is much to enjoy—the air, the near peaks and glaciers, and the distant view. But many must have received another impression—of the *insurgent* nature of life. Not only are there many beautiful flowers coming up at the thinned edge of the snow on most inhospitable ground, but there is a rich insect life and quite a number of birds, besides hundreds of things unseen. Very conspicuous are the large, white-bellied Alpine swifts, perhaps the most rapid of all birds in their flight, continually swirling about in the cold air, with a note of victory in their cry, the very emblems of insurgent life. Shy marmots whistle among the rocks and strange flocks of white moths float up in the mist, rising like the souls of animals

that have died far below. Everything is unpropitious, yet life is abundant; we feel what Bergson calls the *élan*, the spring, the impetus that is characteristic of livingness. We feel the *insurgent, indomitable, self-assertive character of living organisms*,—something foreign to the purely physical.

On the links, perhaps nearer home for most of us, the whole surface of the grass is sometimes covered for acres with threads of gossamer. If we bend down we see the earth quivering as far as the eye can reach. In some of the hollows still unsunned, we see what R. L. Stevenson meant by "the fairy wheels and threads of cobwebs dew-bediamonded." When the sun catches the quivering threads, the silvery robe changes to one of gold. Who can see this without thinking of Goethe's words about Nature: "She moves and works above and beneath, working and weaving, an endless motion, birth and death, an infinite ocean, a changeful web, a glowing life." The beauty of it is increased, not decreased, if we happen to know a little about the natural history of gossamer, for most of these threads are the residues of the ballooning activity of thousands of small spiders. The sight as we see it is a good emblem of *the intricacy of the web of life*.

Three examples are as good as three hundred, for what we mean is simple enough. Whether

we watch the literal myriads of starlings circling over one of their favourite resorts, resembling from a mile off the thick smoke writhing over a crater, or a swarm of locusts darkening the sky with a thick curtain of wings, we feel the abundance of life. When we watch the flying fishes rising in hundreds before the prow of the steamer, like grasshoppers before us as we walk through a rich meadow; or the storm-petrels flying over the waves with dangling feet, never touching land except to nest; or the salmon leaping the falls; or the elvers on their journey upstream; we feel the insurgence of life. When we gaze at the cut stem of a huge American Sequoia, whose annual rings show us that it was a sapling a few years after the fall of Rome, we are in the presence of another form of the Will to Live. And what shall we say of the emotional value of looking backward over the history of organisms, to see life slowly creeping upwards through the ages, adapting itself to every niche of opportunity, expressing itself with increasing freedom and fulness, with more and more emergence of Mind?

Wherever we turn in our Natural History we are brought up against the abundance, the insurgence, the effectiveness, the intricacy, and the mystery of life—in all of which, in addition to the great gift of unsolved problems, there is unstinted food for fancy, an unending supply of

the raw materials of poetry, and a continual reinvigoration of those primary and fundamental Nature impressions without which we cannot really make our heritage our own. And when what Science gives us is transfigured by Art, *then*—if we may wrest a little the words of an artistic genius: "The very aspect of the world will change to our startled eyes. . . . Dragons will wander about in waste places, and the phœnix will soar from her nest of fire into the air. We shall lay our hands upon the basilisk and see the jewel in the toad's head. Champing his gilded oats, the hippogriff will stand in our stalls, and over our heads will float the blue-bird singing of beautiful and impossible things, of things that are lovely and that never happen, of things that are not and that should be."

Opposition between Science and Feeling.—We have been trying to suggest, indirectly rather than formally, that Science and Art are complementary. Science has a great deal to offer to Art in the way of raw materials,—and these of a kind that Art is ennobled in working with them. On the other hand, Science is cold without Art. But while this is so, it cannot be denied that the artistic and the scientific mood are in some measure opposed. There is an antithesis —which easily becomes an antipathy—between them. The reason for this is obvious: Science

aims at being unemotional and impersonal; Art is intrinsically emotional and personal.

We have spoken of the pleasure which Man has in the contemplation and study of Nature, but it must be granted that the scientific mood often intrudes on our delight, elbowing us away from the emotional window. Yet the end is always that the window is widened. Darwin once expressed the delight he had when on a rare occasion he surrendered himself under the trees to the child's pleasure of just watching the birds and insects and all the rest, without vexing himself for once over the problems of origin. But how he has widened the emotional window for mankind, for all who feel the grandeur of the evolution-idea!

Keats could not forgive Newton for robbing mankind of the wonder of the rainbow,—but when minor mysteries disappear, greater mysteries stand confessed. Science never destroys wonder, but only shifts it, higher and deeper. When the half-Gods go, the Gods arrive, to the æsthetic as well as to the religious mood. For it is our experience that there is always something finer, higher, grander than we saw at first. Should we not get back oftener to the emotional realization of height above height, which is expressed in Emerson's picture of the little child looking up through the maple branches?—

"Over his head were the maple buds,
And over the tree was the moon,
And over the moon were the starry studs
That drop from the angels' shoon."

Our general position is a very simple one. We are enthusiastic believers in the value of Science in furnishing descriptive formulæ which facilitate both our intellectual and our practical grasp of Nature. But we do not feel that the generalizations of Science are by themselves satisfying to us. Rightly or wrongly we share the ordinary human longing for explanations, and we are not affected by being told that it is an unhealthy appetite. We believe that nature-poetry and religious feeling are alike complementary to Science. Both aim at getting beyond Science by other methods, intuitive and instinctive rather than intellectual—and *we do not think that they fail.*

Summary.—*There are three relations between Science and Art:* (1) *there is a scientific study of æsthetics;* (2) *Science has enormous stores of what may be called the raw materials of Art; and* (3) *there is an interesting psychological opposition between the two moods. Æsthetics is a psychological science which inquires into the characteristics of that familiar experience which we call enjoying Nature or Art, and of the rarer experience of pro-*

ductive artists. Man's emotional relation to Nature is primal and fundamental. The fundamental and ancient impressions are of the world-power, of the immensities, of the pervading order, and of the universal flux. To these modern science has added impressions of manifoldness, intricacy, inter-relatedness, and evolution. Nature is more than a mirror of our moods; the fundamental impressions are impersonal. While they have scientific validity, they are hardly less important in supplying the raw materials of poetry. Yet there is undoubted opposition between the scientific and the artistic mood; when either is in the saddle it must keep the other at a spear's length.

CHAPTER VII

SCIENCE AND RELIGION

"Have a glimpse of incomprehensibles; and thoughts of things which thoughts but tenderly touch. Lodge immaterials in thy head; ascend into invisibles; fill thy spirit with spirituals, with the mysteries of faith, the magnalities of religion, and thy life with the honour of God."

—SIR THOMAS BROWNE.

The Aim of Science and the Attitude of Religion—From Practical Problems to Religion—From Emotional Strain to Religion—From the Riddles of the Universe to Religion—The Voices of Nature—The Conflict between Science and Religion—Herbert Spencer's Position—Contributions of Science to Religion—Summary.

MUCH has been written on the relations between Science and Religion, and the history of the so-called conflict between them is long. What we propose to do in this short chapter is to explain a certain point of view which appears to us to make for clearness of thought. Our view is that Science and Religion are incommensurables, that there is no true antithesis between them. Let us explain.

THE AIM OF SCIENCE AND THE ATTITUDE OF RELIGION.—As we have already seen, the aim of Science is to discover the general laws of what goes on, to formulate the sequences in the simplest possible terms,—terms which are either the immediate data of experience or verifiably derived from these. It has a definite aim, which is to describe things as they are and as they have been, and to discover the laws of all processes; it has definite methods of observation and experiment; it has its own "universe of discourse" which does not include transcendental concepts and offers no ultimate explanations.

We cannot define Religion, but we use the word to include all recognition—whether practical, emotional, or intellectual—of an independent spiritual reality. It is evidently something altogether different from Science; it is beyond the high tide-mark of everyday emotion and it is on the far side of intellectual curiosity.

Religion implies a realization of a higher order of things than those of sense-experience, and it has the usual three sides of feeling, intellectual conviction, and activity. "Religion," said Prof. James, "has meant many things in human history. . . . I use the word in the supernaturalist sense, as declaring that the so-called order of nature, which constitutes this world's experience, is only one portion of the total universe, and that there

stretches beyond this visible world an unseen world of which we now know nothing positive, but in its relation to which the true significance of our present mundane life consists. A man's religious faith (whatever more special items of doctrine it may involve) means for me essentially his faith in the existence of an unseen order of some kind in which the riddles of the natural order may be found explained" (*The Will to Believe*, 1903, p. 51). Prof. A. E. Taylor writes: "Specifically religious emotion, as we can detect it both in our own experience, if we happen to possess the religious 'temperament,' and in the devotional literature of the world, appears to be essentially a mingled condition of exaltation and humility arising from an immediate sense of communion and co-operation with a power greater and better than ourselves, in which our ideas of good find completer realization than they every obtain in the empirically known time-order" (*Elements of Metaphysics*, 1903, p. 390).

Taking these descriptions as typical we see that Religion includes what a man does, and feels, and thinks when he has reached the limit of his ordinary practical, emotional, and intellectual tether. It transcends the ordinary and implies a certain exaltation of feeling—apart from which its activity, its art, its ideas are quite undiscussable. Its language is not that of the street,

nor of the studio, nor of the laboratory. And just as it is impossible to speak two languages at once, so it is false antithesis to contrast scientific and religious interpretations,—they are incommensurable.

We wish in a simple historical way to consider some of the pathways that have led and still lead men to religious experience. In this way we may be able to discern in part how it is that the growth of Science influences Religion, although they are incommensurables. We would remind ourselves and our readers that the whole subject should be treated with reverence and sympathy, for it is hardly possible to exaggerate the august rôle of religion in human life. Whatever be our views, we must recognize that just as the great mathematicians and metaphysicians represent the aristocracy of human intellect, so the great religious geniuses represent the aristocracy of human emotion. And in this connection it is probably useful to bear in mind that in all *discussions* about religious ideas or feelings we should ourselves be in an exalted mood, and yet "with a compelling sense of our own limitations," and of the vastness and mysteriousness of the world.

From Practical Problems to Religion.—Man has three main relations with Nature and with his fellow-men,—practical, emotional, and intellectual—and along each of these three lines

there is a pathway to religion. For untold ages Man has been dependent upon Nature, and she has had many hard lessons to teach him as to food and safety, as to health and conduct. Nature has trained her "insurgent son" so that he has entered more and more fully into his kingdom. This has happened partly because Man listened to good purpose to the voices of Nature and to voices which do not belong to Nature at all, but partly because Man, having in him the central secret of life which we call variability, has changed progressively from generation to generation as he has been subjected to Nature's sifting in the Struggle for Existence. These three words, which tell half of pain and half of happiness, mean for Man that he fought with wild beasts till he worsted them or tamed them, that at great cost he sifted out the wholesome from the poisonous herbs, that, cowering and crouching for ages, he watched the elemental forces of Nature till he wrested from them their secrets, that he has been to his fellows, too, since the beginning, the strangest mixture of self-assertiveness and sympathy, and that he has kept up an age-long endeavour after well-being—always at his best when rowing hard against the stream.

Nature's has been a stern school; she has let no slackness go unpunished; and the voice that we hear echoing down the ages is Struggle, En-

deavour, Struggle. Sparing only those who will accept the life of ease—which we call parasitism—Nature has always tended to eliminate the sluggish, the unbalanced, the uncontrolled, the unwholesome. Wild animals in Nature have parasites, but the occurrence of organic disease amongst them is rare, and its elimination is rapid. Nature is all for health. And for those who get anything of a fair start, health is a curiously sensitive index of morals,—and not for the lower reaches only.

Civilization has indeed mitigated the severity of Nature's Spartan methods, and has thrown off the yoke of Natural Selection, but it has not put an end to struggle nor the need for it. We interfere with Nature's winnowing at every turn, and we are awakening to realize the penalty we have to pay for having abandoned Nature's policy without adopting a really humaner one of our own. We are face to face with ugly and terrible social arrears—the results of our easy-going regime in which superiority does not necessarily profit by the rewards of superiority, in which inferiority is shielded from the evils it entails. Since we cannot return to Nature's stern regime, which Plato approved, it behoves us more strenuously to substitute for Natural Selection a similar method on a higher turn of the spiral—namely, a stringent policy of Rational and Social Selection which will not be afraid to be firm in the present

so that we may be less cruel to the future. We cannot return to Nature's tactics, but we must adhere to her strategy or perish miserably.

Huxley insisted with his usual incisiveness that our only chance of ethical progress was to combat the cosmic process, for what he saw in Nature was a vast gladiatorial show, a ubiquitous Ishmaelitism, every living creature for itself and extinction taking the hindmost. But he did not adequately appreciate the fact that throughout the struggle for existence in Nature, there is often a pathway to survival and success through increased co-operation, kindliness, and mutual aid, as well as through increased competition and self-assertion. And it is this line of combination and mutual aid that man must especially follow; it is the one he *has* followed in making some of his greatest advances.

Moreover, is it not generally admitted that the moral ideal is one of self-realization by working for our social group, by being good citizens in fact,—a self-realization which implies our private subordination to the general weal? And is not this the deeper aspect of Nature's strategy, that the individual living creature realizes itself in its inter-relations, and has to submit to being lost that the welfare of the whole may be served? There is much indeed to be said for the thesis: that the ideals of ethical progress—through love

and sociality, co-operation and sacrifice, may be interpreted not as mere utopias contradicted by experience, but as the highest expressions of the central evolutionary process of the natural world.

To return to our general theme, we must admit that for long ages Man learned in a hard school, and that the severity of the lessons often brought him to his knees. It seems to be an historical fact that many a man has become religious when he reached the limit of his practical endeavour and was baffled. When our naïve ancestors had done all they could and felt themselves powerless and were afraid, they offered gifts, or sacrifices, or prayers. It is surely true that the fear of Nature has sometimes led men to the fear of the Lord.

But as Man has become more and more master of Nature, he has ceased to offer sacrifice or to pray for rain; and this pathway to religion is not so well trodden now as it was in ancient days. Let us think vividly of our ancestors—living in caves, fearful of wild beasts, often dying of hunger or of poison, without wood-work or metals, without fire, without foresight, and quite unable to look to the general weal. What a contrast between this picture and our life to-day. For now-a-days, the serpent that bites Man's heel is in nine cases out of ten microscopic; year by year Man increases his mastery over the physical

forces; he coins wealth out of the thin air; he annihilates distance with his deep devices; he makes the ether carry his messages; he is extending his kingdom to the heavens; and he is making experiments on the control of life. And there is nothing to lead us to believe that Man has more than begun to enter into his kingdom.

The increasing mastery of Nature and the associated enormous increase in human comfort and prosperity must be traced to the application of science, and perhaps this is one of the indirect ways in which scientific development hinders rather than helps the growth of religious feeling. This is a very simple consideration, but surely one of importance, that the scientific strengthening of Man's foothold in the struggle for existence *tends*, for rougher minds at least (and "we are not all the finest Parian"), to close one of the pathways to religion. In saying this we are not unaware that the practical tasks ahead are stern enough. For man has still a very imperfect mastery of himself and our civilization is full of misery. In face of the often terrible failures of human endeavour, the element of tragedy in things as they are, and the chill that follows the vision of our fair earth and all that it contains becoming cold and cindery as the moon, many a one of great repute in the world of science—we think of men like Clerk Maxwell or Kelvin—seeks

to steady himself in the thought of some Abiding Reality, saying as of yore, "I will lift up mine eyes unto the hills."

From Emotional Strain to Religion.—We have already spoken of Nature's appeal to the human emotions,—which seems to us to be one of the big formative influences in human evolution. Admitting that the emotional note varies with our science, from age to age, and from race to race, we venture to say that a love of Nature is an essential human relation—lost for a while in ultra-urban conditions—which makes all the world kin, and is one of the saving graces of life.

Our present point is that the sense of wonder, for instance, in the presence of Nature, which lies near the roots of science and of philosophy, is and will continue to be one of the footstools of religion. Nature is at times so overpowering in its beauty or in its awesomeness, that we feel it too big for our humanity. Thus at the limit of his emotional tension Man has often become a worshipper. Some indeed—poets and painters and musicians—find relief in their art, and in this some maintain that there is an essentially religious quality. What seems to us quite clear when we consider such magnificent pieces of poetic literature as the Nature-Psalms is this, that men surcharged with emotion in the contemplation of Nature may keep their sanity by finding a

religious expression. To the author of Psalm xxix, for instance, the thunder-storm that passed over the country was a revelation of God. We miss the whole point if we suppose that the poet meant to say that the thunder was caused by God speaking. "He was not in the passionless and prosaic state of seeking an explanation of the thunder; he was expressing religious experience of the most exalted kind." He was far beyond the confines of science, he has been greatly thrilled by the storm, and in his exalted state of feeling his emotion became religious, he heard God's voice.

Similarly in Man's emotional relations with his fellows there are heights of joy and depths of sorrow from which the transition to religious feeling is natural, to certain temperaments at least.

Can it be said that the development of science has in any way affected the frequency with which the emotional pathway to religion is followed? It may be that in the rapid extension of scientific thinking and scientific knowledge some have lost the sense of wonder that is due to relative ignorance without gaining that which comes from knowledge. It may also be that the extension of psychological analysis to all manner of emotions has induced a curious self-consciousness that inhibits spontaneity of feeling.

We think, however, that if there is a decadence of delight and reverence in the presence of Nature, it must be due rather to the conditions of modern urban civilization than to the spread of Science. Many men, some by choice, and some under coercion, have got quite out of touch with Nature, to their own great loss. For Man was cradled and brought up in Nature, and if, because of civilization, he cannot any longer continue to live in the old home, it is a condition of emotional sanity that he should periodically return there, as the migratory birds do. It is this old-established association, we think, that gives deep import to that "uprush of feeling from below the ordinary level of consciousness" which we experience when we allow the beauty of Nature to play upon us. In Emerson's transcendental language, "Nature is the organ through which the universal spirit speaks to the individual."

From the Riddles of the Universe to Religion.—Having referred to Man's practical and emotional relations with Nature and with his fellows, we come to the third relation, which is intellectual or scientific. The first voice of Nature is Endeavour, the second is Enjoy, the third is Enquire. For hundreds of thousands of years, Nature has been setting Man problems, leading him gradually from the practical to the more abstract. On the one side there is Man—inquisi-

tive like an animal, but with deeper devices; on the other side there is Nature,—a rare collection of riddles. The sciences are the solutions.

In olden times when the natural sciences were young, when few methods of investigation were known, Man found himself hemmed in by the unknown and mysterious, so oppressively at times that a religious formulation was sought as a welcome refuge. At the end of his intellectual tether, Man has never ceased to become religious.

Now-a-days, however, the rapid development of Science has cleared away a hundred minor mysteries. Problem after problem has been solved, and the correctness of the solutions has been verified in practical mastery of Nature. Man's intellectual tether has been greatly lengthened, and there are not a few who give the ignorant to understand that most of the enigmas of Nature have found their answers.

But, as we have already seen, the solutions that Science offers have obvious limitations. They do not satisfy most men, who will persist in asking questions which Science never asks,—questions about beginnings and ends, about meanings and values. Let us recall for a moment some of the limitations. Scientific formulations are always in terms of something "given" which is unexplained. In its historical treatment of things

Science always begins—not at the beginning, for that is impossible, but from something "given" which it does not explain. Moreover, in linking happenings together, it is only in a limited set of cases that Science can tell how the result is as it is.

In the common denominator to which Science reduces things, in the sequences where the resultants seem qualitatively different from their antecedents, in the origins from which science starts in its genealogies, there is mysteriousness. All our scientific experience is rounded with mystery. As Sir E. Ray Lankester has said: "No sane man has ever pretended, since science became a definite body of doctrine, that we know or ever can hope to know or conceive of the possibility of knowing whence the mechanism has come, why it is there, whither it is going, and what may or may not be beyond and beside it, which our senses are incapable of appreciating. These things are not 'explained' by science and never can be."

If we will have for our human satisfaction some answer to questions such as these, which lie *beyond Science*, then it must be a transcendental answer, and that means for most men, who prefer to think naïvely, a religious answer. As Coleridge said: "All knowledge begins and ends with wonder, but the first wonder is the child of ignorance; the second wonder is the parent of adoration."

The Voices of Nature.—Let us draw together the threads of this simple argument, which is meant to show how, from the nature of the case, the progress of science must influence the growth of the religious mood. Nature is so great—perhaps infinitely great—that we need not be too much afraid of verbal personification, nor of speaking, for purposes of convenience, of the three voices of Nature when we simply mean the impulses that come from the threefold —practical, emotional, and intellectual—relation between Man and Nature. We are thinking, of course, of wordless voices, as is said with sublime contradiction in the nineteenth Psalm: "Day unto day is welling forth speech, and night unto night is breathing out knowledge; yet there *is* no speech, and there *are* no words; their voice has no audible sound, yet it resonates over all the earth."

We have hinted at the historical fact that in listening to these voices, men have often passed into religious experience, almost by a kind of coercion. When a man after extreme struggle is utterly baffled practically, he may kneel in prayer; when a man is penetratingly thrilled with emotion he may be borne by its ecstasy into worship; and when a man at the end of his scientific tether is entirely unsatisfied with his formulæ—necessarily as cold as they are true—he may

pass by a third portal into conviction of religious truth.

These seem to us to be historical statements. Though the three pathways indicated may not be the only ones, nor the best, they *are* three pathways along which men have passed to religion. Not that they lead inevitably to religious experience, for the practically baffled may become a resigned and even cheerful fatalist, the emotionally thrilled may find a solution in some form of art, and the unsatisfied scientific inquirer may settle down into a contented positivist. But a religious result is just as common. In some degree the pathways may be called coercive, indicating at sort of bad-weather recourse to religion, but perhaps bad weather of the sort indicated is part of a normal human experience.

It seems fair to add another consideration, that in listening to what we have called the three voices of Nature, man may be disciplined to hear even more august voices. Man's struggles for food and foot-hold may give him grit that helps towards and in much higher grades of endeavour; to be thrilled with beauty may be a step to loving goodness; and to try to find out what is scientifically true in Nature may be the beginning of "waiting patiently upon the Lord."

While we are convinced that to listen to what we have called the three voices of Nature is a

normal and necessary discipline of the developing human spirit, we do not think that Man can find abiding satisfaction in Nature's voices alone. Invigorating, inspiring, and instructive they certainly are, but, as we have seen, they are full of perplexities, and it is with a certain sad wistfulness that we hear their echoes dying away in the quietness of our minds like the calls of curlews on the moorland as they pass farther into the mist. Happy, then, in that quietness are those who have what Sir Thomas Browne called "a glimpse of incomprehensibles, and thoughts of things which thoughts but tenderly touch."

It must be carefully noted that we have spoken only of those pathways to religion which the growth of Science has most directly affected. We have not spoken of the ethical approach to religion, by which many take refuge from the contradictions of moral experience, nor of the approach to religion which is followed by those who are able to see in history, and especially in the Founder of Christianity, a direct Revelation of what is otherwise only groped after.

The Conflict between Science and Religion.—It was Clerk Maxwell who spoke of the absurdity of trying to keep "idea-tight compartments" in our minds, and although some men appear to achieve considerable success in keeping their scientific convictions unrelated to their

religious convictions, there is an element of grotesqueness in the feat. Insulation of this sort is unnatural, and when very successful it is pathological. Obviously our whole life should be correlated, and it is the endeavour after unification that is in part responsible for the long-drawn-out "conflict between science and religion"—a conflict which is often deplored, whereas it means a wholesome keenness of interest and an ideal of clearness and consistency.

The "conflict between science and religion" has several forms, which must be distinguished from one another. (*a*) In the first place, religious feeling is usually associated with a content of beliefs, directly based on religious experience or dependent on an interpretation of human history and of Nature. In many cases the beliefs that rest on interpretation form part of a tradition accepted unquestioningly by facile minds, or independently tested by those who are sufficient for such inquiries. To some extent, but to a continually decreasing extent, these religious beliefs touch the world of the concrete, and a clashing with science must arise whenever and wherever the form of the religious belief is inconsistent with the results of science. A typical instance occurred in the infancy of experimental science when Galileo's new astronomy could not but clash with a religious belief which was for

the time being wrapped up with the assumption that the earth was the steadfast hub of the solar system. Now-a-days, however, the religious mind is not in the least excited over the question whether the earth goes round the sun, or the sun round the earth, and this has been one of the uses of the "conflict between Science and Religion," that the particular "body" which a religious idea takes, has been more and more sublimed. In most cases the religious idea has become clearer in the process.

We may say, then, that if the form or expression of a religious belief is contradictory to a well-established fact in the order of Nature, then clashing is inevitable. But to see in this an antithesis between the scientific formula and the religious idea is a misunderstanding.

(*b*) In the second place, conflict and confusion have arisen by misguided attempts to combine religious and scientific formulations in the hope of thus making things more intelligible. An instance may be found in the history of theories of organic evolution. The business of the scientific evolutionist is to show how verifiable factors may have co-operated to produce the marvellous results which we see around us to-day. It goes without saying that this task has not yet been crowned with success. The results often seem strangely out of proportion to the known causes.

In particular it is difficult to give a scientific account of the "big lifts" in the history of the world of life. It gives us pause to think of the origin of Vertebrates, of Birds, of Mammals, of Man. We cannot speak with much confidence of the operative factors. In spite of this unsatisfactory ignorance, however, the scientific mind recoils with a jerk from the assumption of "spiritual influxes" or mystical powers of any sort interpolated from outside to help the evolving organism over the stiles of difficulty. The scientific task is certainly unfulfilled; it may be beyond human attainment to complete it; but we must not try to speak two languages at once.

(*c*) In the third place, just as religion is often associated with forms of belief which are unessential to it, and which may be inconsistent with scientific conclusions, so science often goes beyond its own sphere and becomes associated with philosophical doctrines which are unessential to it, and which may conflict with religious convictions. Thus, to take a familiar instance, materialism is not a scientific conclusion, but a philosophical doctrine which many students of science have embraced. And materialism is inconsistent with most forms of religious belief and experience. The point that we wish to make is that the antagonism in this case is not between religion and

science, but between religion and a particular philosophy.

(*d*) In the fourth place the application of scientific methods of investigation to the forms of religious activity, tends, in the eyes of some at least, to rob them of that mystic atmosphere apart from which the religious spirit cannot breathe. The genetic method has penetrated into the realms of religion, and we read of the evolution of religious ideas, feelings, and rites. They are "explained" and their survival is accounted for. Moreover, the psychologist and even the physiologist has had his innings, and it seems to some as if religious phenomena were losing all their religious character. Like tender plants drawn out from shadowy recesses, they wither quickly in the glare of common day. Little wonder, then, that those to whom religious experience is the greatest reality of their life should regard science as a foe.

(*e*) In the fifth place, there is an indubitable contrast between the scientific and the religious mood; they cannot be simultaneous; they are not likely to be equally strong in the same individual; and there are reasons why the culture of the former is not favourable to the latter. It is important to inquire into these reasons. How far is the opposition essential and necessary? How far is it due to the limitations of our faculties and to misunderstanding?

It cannot be that Science is satisfied with what it has done in the way of giving an account of things, or supposes that it will soon be able to congratulate itself on having cleared up all mysteries and explained everything. That is a view held only by the vulgar and half-educated. As we have said so often, Science gives no ultimate explanations. It is not its business to try to do so. When Laplace, answering Napoleon's question about God, said that he "had no need of that hypothesis," he obviously meant that that august concept was foreign to the astronomical "universe of discourse." Nor can it be said that Science engenders an irreverent spirit; the biographies of all the greatest scientific investigators show the reverse. The irreverent and the unwondering are to be found among those who know least, not among those who know most. It is true that minor mysteries disappear, or, at least, that they cease to be mysterious in a superficial way, but it has been the experience of many a student of Science that when the half-gods go the gods arrive.

To understand the antithesis we must remember how our habitual occupation influences the mind. It is the everyday business of Science to work with facts, to describe these, testing and measuring, to search out causes, to discover chains of sequence —and all in such a way that the work done may

be universally verifiable by all competent inquirers. A scientific datum should be quite impersonal, and the statement of it should be quite uncoloured by any emotion. This habitual occupation is bound to react on the organism; it does not in itself favour that subjectivity which is characteristic of religious feeling.

We have to remember also that the scientific spirit has been slowly learning the great lesson, driven home by positivism—that its formulations must be freed from the vague and verbal. Science ever brandishes "William of Occam's razor": "Entities are not to be multiplied beyond necessity."

Furthermore, it seems that some importance must be attached not only to the sceptical habit, which is distinctively scientific—the testing, verifying spirit—but also to the agnostic frame of mind. The scientific inquirer is aware of so many enigmas, so many unsolved or half-solved problems, that it is almost habitual to him to say: "I do not know," "I do not understand." He has learned to refrain from formulation when the data are insufficient; he is accustomed to be agnostic. Not that he folds his hands saying, "We do not know and we shall never know," his is an active agnosticism. But being accustomed to patience, and having seen the solution of much that his forefathers called insoluble,

he will not make haste to adopt transcendental explanations of particular events. As Prof. Boutroux puts it: "The history of science proves that we have a right to affirm a continuity between what we know and what we do not know. This is why the expression, 'scientifically inexplicable,' is really without meaning. A mysterious force, a miraculous fact, assuming that the fact exists, what is it but a phenomenon which we are unable to explain with the help of the laws that we at present know. If the impossibility is confirmed, science will go on to seek for other laws."

In this connection, we venture to quote a well-known passage from the late Prof. William James's *Will to Believe* (1903). "When one turns to the magnificent edifice of the physical sciences, and sees how it was reared; what thousands of disinterested moral lives of men lie buried in its mere foundations; what patience and postponement, what choking down of preference, what submission to the icy laws of outer fact are wrought into its very stones and mortar; how absolutely impersonal it stands in its vast augustness,—then how besotted and contemptible seems every little sentimentalist who comes blowing his voluntary smoke-wreaths, and pretending to decide things from out of his private dream! Can we wonder if those bred in the rugged and manly

school of science should feel like spewing such subjectivism out of their mouths?" We must remember, however, James's subsequent conclusion that "our passional nature not only lawfully may, but must, decide an option between propositions, whenever it is a genuine option that cannot by its nature be decided on intellectual grounds."

Our own position is this. Science seeks to answer certain kinds of questions in regard to Nature and Man and the history of both. These answers are very far from being complete, for the world is very large and science is very young. But even if the answers were as complete all round as they are already in parts, and if there were also answers to all the scientific questions which we do not yet foresee nor know how to ask, yet they would not be of a kind to satisfy the whole nature of the ordinary man. We get hints of complementary answers in poetic and religious feeling, and we see no reason to believe that the only approach to Truth or Reality is by the scientific method. The satisfaction we reach in poetic and religious feeling is transcendental, on a different plane from scientific satisfaction. It is unverifiable, incommunicable, mystical, but—for ourselves—true. In its mystical character there is danger, but the safeguard is in steadying the mind with Science and Philosophy—with

which our poetry and religion must be harmonious. Apart from this, another test of the validity of our mystical feelings and transcendental constructions is their value in our life.

HERBERT SPENCER'S POSITION.—As we have referred to the religious convictions of intellectual giants like Clerk Maxwell and Lord Kelvin, so we would in fairness illustrate a different position by reference to Herbert Spencer, who also belonged to the kingdom of genius. Disagree with his views as one may, one cannot doubt either the magnitude of his intellect or his passionate sincerity.

In early days he was an uncompromising critic of particular theological doctrines and religious customs, but a wider knowledge convinced him almost against his will that some sort of religious cult has been an indispensable factor in social progress. He looked forward to a stage in which, "recognizing the mystery of things as insoluble, religious organizations will be devoted to ethical culture.

"Thus I have come more and more to look calmly on forms of religious belief to which I had, in earlier days, a pronounced aversion. Holding that they are in the main naturally adapted to their respective peoples and times, it now seems to me well that they should severally live and work as long as the conditions persist, and, fur-

ther, that sudden changes of religious institutions, as of political institutions, are certain to be followed by reactions.

"If it be asked why, thinking thus, I have persevered in setting forth views at variance with current creeds, my reply is the one elsewhere made: 'It is for each to utter that which he sincerely believes to be true, and, adding his unit of influence to all other units, leave the results to work themselves out.'"

Largely, however, Spencer's change of mood in regard to religious creeds and institutions resulted from "a deepening conviction that the sphere occupied by them can never become an unfilled sphere, but that there must continue to arise afresh the great questions concerning ourselves and surrounding things; and that, if not positive answers, then modes of consciousness standing in place of positive answers must ever remain."

We venture to quote a somewhat lengthy passage because of its quite unique interest in regard to the relations between science and religion:—

"By those who know much, more than by those who know little, is there felt the need for explanation. Whence this process, inconceivable however symbolized, by which alike the monad

and the man build themselves up into their respective structures? What must we say of the life, minute, multitudinous, degraded, which, covering the ocean-floor, occupies by far the larger part of the Earth's area; and which yet, growing and decaying in utter darkness, presents hundreds of species of a single type? Or, when we think of the myriads of years of the Earth's past, during which have arisen and passed away low forms of creatures, small and great, which murdering and being murdered, have gradually evolved, how shall we answer the question: To what end? Ascending to wider problems, in which way are we to interpret the lifelessness of the greater celestial masses, the giant planets, and the Sun; in proportion to which the habitable planets are mere nothings? If we pass from these relatively near bodies to the thirty millions of remote suns and solar systems, where shall we find a reason for all this apparently unconscious existence, infinite in amount compared with the existence which is conscious—a waste Universe as it seems? Then behind these mysteries lies the all-embracing mystery—whence this universal transformation which has gone on unceasingly throughout a past eternity and will go on unceasingly throughout a future eternity? And along with this rises the paralysing thought: What if, of all that is thus incomprehensible to us, there

exists no comprehension anywhere? No wonder that men take refuge in authoritative dogma!

"So is it, too, with our own natures. No less inscrutable is this complex consciousness which has slowly evolved out of infantine vacuity—consciousness which, during the development of every creature, makes its appearance out of what seems unconscious matter; suggesting the thought that consciousness in some rudimentary form is omnipresent. Lastly come insoluble questions concerning our own fate: the evidence seeming so strong that the relations of mind and nervous structure are such that the cessation of the one accompanies dissolution of the other, while, simultaneously, comes the thought, so strange and so difficult to realize, that with death there lapses both the consciousness of existence and the consciousness of having existed.

"Thus religious creeds, which in one way or other occupy the sphere that rational interpretation seeks to occupy and fails, and fails the more it seeks, I have come to regard with a sympathy based on community of need: feeling that dissent from them results from inability to accept the solutions offered, joined with the wish that solutions could be found" (Spencer, 1893).

Contributions of Science to Religion.—Some people are disappointed because scientific investigation gives no direct support to

religious convictions, but this shows a misunderstanding of what is meant by science and by religion. Science establishes conclusions which the religious mood may utilize, just as philosophy utilizes them, and transfigure, just as poetry transfigures them; but it is the common confession of the scientific mood throughout all the ages that we cannot "by searching find out God."

But is it not much that Science discloses more and more fully the intelligibility, the orderliness, and the progressiveness of Nature? These are big intellectual assets. Is it not much that Science discloses more and more fully the wonder of the world—the immensities and the intricacies, the changing order and the orderly changes besides all the beauty in depths and heights which the unscientific eye cannot see? These are big emotional assets. Is there not practical value, too, both of encouragement and warning, in the scientific view that it is an ascent, not a descent, that is behind us—and in front of us too, we hope? Everything seems to indicate that it is an increasingly controllable future that lies before us here, and it surely adds zest to our life to feel that we can share in the "increasing purpose" of evolution, in the working out of what seems like a great and beautiful thought.

It is also fair to recognize that Science has done well by Religion in eliminating much that

is superstitious, and it seems very unlikely that its useful function in this direction has been completed. As the late Prof. W. James said: "What mankind at large most lacks is criticism and caution, not faith." "What some," he went on to say, "most need is that their faiths should be broken up and ventilated, that the north-west wind of science should get into them and blow their sickliness and barbarism away."

SUMMARY.—*Science and Religion are incommensurables, and there is no true antithesis between them—they belong to different universes of discourse: Science is descriptive and offers no ultimate explanation; Religion is mystical and interpretative, implying a realization of a higher order of things than those of sense-experience. Men are led to religion along many pathways—from the contradictions of the moral life, from the facts of history, and from what is experienced at the limits of practical endeavour, emotional strain, and intellectual inquiry. It is not difficult to see why the rapid development of Science should have affected, for a time of transition at least, the frequency with which men tread the last-named three pathways to religion—namely, from baulked struggle, strained emotion, and baffled inquiry. The so-called "conflict between science and religion" depends in part on a clashing of particular expressions of religious belief with facts of science, or on a clashing of*

particular scientific philosophies with religious feeling, or on attempts to combine in one statement scientific and religious formulations, or on the application of psychological inquiry to the phases of religious experience, or on the contrast of the two moods. But the bulk of the conflict is due to a misunderstanding, to a false antithesis between incommensurables. While Science can give no direct support to religious convictions, it establishes conclusions which the religious mood may utilize, just as philosophy utilizes them, and transfigure, just as poetry transfigures them.

CHAPTER VIII

THE UTILITY OF SCIENCE

"The end of our foundation [Salomon's House in the *New Atlantis*] is the knowledge of causes and the secret motions of things; and the enlarging of the bounds of human empire, to the effecting of all things possible."—FRANCIS BACON.

Science for its own Sake—Science and Practical Lore—Science and Occupation—Illustrations of the Practical Utility of the Sciences—Danger of Utilitarian Criteria—Fundamental Value of "Theoretical Science"—Historical Illustrations—Socialized Science—Summary.

SCIENCE FOR ITS OWN SAKE.—To see things and happenings clearly, both in themselves and in their relations to other things and happenings, is the aim of science. And no one who enjoys scientific work—whether at the humble level of accurate description, or at the high level of discovering a formula—cares to hear much about the "utility of science." No artist likes utilitarian valuations of his art, and the scientist understands him in this at least. I also am an artist, he says, or words to that effect, meaning (1) that a scientific investigation is, like a picture,

an endeavour to get at the setting and significance of things or events; (2) that there is a delight and an endeavour in scientific workmanship that is its own reward; and (3) that in the higher reaches of science, the discovery of a formula, a general law, a pedigree, a homology, an inter-relation—whatever it may be—is in some measure a personal achievement.

"Science for its own sake," like "Art for Art's sake," is an autonomy worth fighting for. Both scientific inquiry and artistic device are natural and necessary expressions of the evolving human spirit, and for this reason a utilitarian apology for either is gratuitous. Scientific inquiry is noble in itself, and it is its own reward. As Bacon said: "We see in all other pleasures there is satiety, and after they be used their verdure departeth. . . . But of knowledge there is no satiety, but satisfaction and appetite are perpetually interchangeable, and therefore it appeareth to be good in itself simply without fallacy or accident."

Science and Practical Lore.—Historical inquiry shows that the concrete sciences grew out of practical lore, and that even after they began to stand on their own legs as independent theoretical interpretations of Nature, they have often received fresh stimulus by coming back to practical problems. Did not botany arise out of

herb-gathering and gardening, and has not botany as a science got an uplift from all its many contacts with human needs? We think of yeast and fermentations, of bacteria and diseases, of diatoms and fish-supply, of breeding experiments and the improvement of our food-plants, of plant-associations and inter-relations in their bearing on the perennial problem of making the most of the Earth for our children as well as for ourselves.

The lore of the hunter, the fisher, the shepherd is older than all zoology, and every thoughtful naturalist will agree that his science runs a risk of losing vitality and real progressiveness if it gets too far away from the actual life of animals as it is lived in Nature. Nay more, that just as a stimulus has been periodically given to zoological studies by the return of a great expedition, such as the *Challenger*, with its enthralling splendour of animate spoils, so the tackling of some practical problem of real moment has often been followed by some impulse to pure science.

It is perhaps going too far to say with Prof. Espinas: "Practice has always gone in advance of theory"; but there is no doubt that science and practice act and react most beneficially upon one another. Science has grown out of practical lore, and it has nothing to gain, but much to lose, by forgetting its origins.

Perhaps, however, there is still some danger—though it is rapidly diminishing—of practical lore refusing the aid of science. The old farmer, who has made his fields and his stock pay for half a century, has no use for the new science of the living earth, which teems with Protozoa as well as with Bacteria, and he has no appetite for Mendelism. The old fisherman, who has sometimes an almost uncanny skill in reading the riddle of the sea—in finding out where he is and where the fish are likely to be—is not athirst for ichthyological instruction, though, as a matter of fact, when he is approached sympathetically, and as one who has something to impart as well as as to receive, he often proves himself an effective student. We need not multiply examples, for the point is a simple one.

Much of the practical lore is thoroughly scientific though it may never have been stated. The use of instruction is to make it conscious, communicable, and more plastic, and to get down to the principles which it unconsciously illustrates. For wonderful as is the lore that comes from instinctive insight to start with and long experience to back this up, it not only tends to die with its possessor, but like instinct, as contrasted with intelligence, in animals, it is apt to be thrown out of gear by some slight change in the conditions of application.

At the same time we feel bound to admit that the endeavour to formulate practical lore is not likely to have more than partial success, for there is an unanalysable element in its higher reaches. This is well known in the case of some of the experienced physicians of the older school whose insight in diagnosis has often excited the wonder and envy of their more scientific successors. Perhaps there was sometimes more hard work behind it than was usually supposed, but it seems certain that in many fields there are men with a remarkable power of intuition, born not made, of whose methods even self-analysis can give no account.

There is no doubt that all the sciences—not excepting psychology and sociology—sprang from concrete experience. Mathematics is abstract enough, but what does its history show? "Man began arithmetic with experience of the number of his fingers and toes, and geometry with experience of the magnitude of his hands, feet, and arms. He went on to use these concrete bodies as standards to measure other bodies. Geometry means the measurement of lands; and the most ancient Egyptian book of mathematics, the papyrus of Ahmes, about 1700 B.C., measures barns, pyramids, and obelisks, and treats solid bodies before proceeding to abstract surfaces. Mathematics, in short, began with concrete bodies,

such as could only be reached by means of experience, and only gradually receded from the concrete to the abstract, to the units of abstract arithmetic, and the points of abstract geometry. The Greeks achieved this analysis from concrete to abstract, and thus converted mathematics from analysis to synthesis, which begins with the abstract unit as origin of number, and with the abstract point as simpler than the line. But the order of discovery was from the concrete and analytical, although afterwards the order of development was from the abstract and synthetic" (Prof. T. Case, 1906, p. 6).

It is good history that the sciences sprang out of the lore of occupations, and it is also a fact of no small ethical importance. "We cannot get away from our ancestors. Just as a physical scientist is a smith, so is the botanist a farmer and shepherd, the zoologist a huntsman, the geographer a sailor, the historian a scald, the doctor a wizard or medicine-man, and the lawyer a scribe. As for the mathematician, his material—the oldest science of all—has been drawn from such a variety of occupations that, if he vividly grasps the spirit of the history of his science (though, unfortunately, this is rarely the case), he should find himself in a very real sense the heir to all the ages, and become imbued with sympathy for all occupations." (Branford, 1904.)

Science and Occupation.—In an address with this title (*Journal of Education*, June, 1904), Mr. Benchara Branford expounds "this deep truth, that all theory, all knowledge, all the broad groups of sciences, originally sprang from the experience gathered by man from one or other of his numerous occupations." "We must not imagine that science floats, as it were, in the clouds, serenely isolated from the hum and bustle and occupations of the busy world, and developing in some mysterious way of its own." "Science ultimately sprang, and is continually springing, from the desires and efforts of men to increase their skill in their occupations by understanding the eternal principles that underlie all dealings of man with Nature and of man with his fellow-men." "And if science ultimately has sprung from, and is continually springing anew from, occupations, science has repaid the debt both by rendering those who follow her teaching more skilled in their occupations and by actually giving rise by her discoveries to absolutely new types of occupations. One of the great conditions of human progress is this unceasing reciprocal relationship between occupation and science, each constantly producing and being produced by the other. Out of many instances I shall choose one striking example of the development of science from occupation.

"Monge was born the son of a French pedlar about 1750. The construction of a plan he made of his native town brought the boy under the notice of a colonel of Engineers, who got him admitted to one of the military schools. His humble birth precluded him from receiving a commission in the Army, but he was taught surveying and drawing; though he was told he was not sufficiently well born to be allowed to attempt problems which required mathematical calculations. At last his opportunity came. He observed that all the plans of fortifications were constructed by long and tedious *arithmetical* calculations from the original observed measurements. Monge substituted for these a *geometrical* process he had invented which produced the plan so quickly that the officer in charge refused to receive it, because professional etiquette required that no less than a certain time should be spent over making these drawings. When once examined, its obvious superiority was recognized. This geometrical process discovered by Monge was nothing less than a new branch of geometry—known to students of engineering as practical solid geometry—a science in which, by the now familiar method of plan and elevation, a solid object can be represented adequately by construction on a plane—a method whose practical, or, let me say, occupational, value

can scarcely be over-estimated, and the further development of which by Monge had far-reaching effects upon mathematical science itself. Here we have a new and distinct branch of science springing directly from the occupation of war, on its engineering side."

Illustrations of the Practical Utility of the Sciences.—The long list of what are called "Applied Sciences"—a term which Huxley hated so heartily—shows the number and the variety of the practical utilizations of Science. We cannot give more than a few examples, which may be multiplied by reference to other scientific volumes, in this Library. Thus while every one knows more or less clearly that astronomy still continues to be of use in navigation, we find in Mr. Hinks's fascinating volume that the science also earns its living by helping the surveyor and the map-maker, and by supplying the world with accurate time. Even to ships upon the sea the astronomers now tell the time of day by wireless telegraphy.

Numerous chemical arts—such as brewing, soap-making and dyeing—were practised before there was a science of chemistry, but the multiplication of these under direct scientific stimulus is past telling. Think only, for instance, of the cyanide processes for the recovery of gold from its ores, of the technical development of ben-

zene and its derivatives, of the electro-chemical industry, of the improvement of steel-making, of the synthetic production of substances like indigo which were formerly procurable only as natural products, and of the utilization of the nitrogen of the air in the manufacture of fertilizers. Among the many practical benefits resulting from the development of physics, we naturally think first of some of the more recent—the telegraph, the telephone, wireless telegraphy, electric motors, and flying machines. From the sciences of the earth man has profited enormously—for they have led him to stores of coal and iron and other buried treasures. From oceanography already there are conclusions of importance in connection with fisheries, and meteorology, another very young science, has already to be thanked for much saving of life and wealth through its prophetic weather reports.

On the biological side we may mention as diverse illustrations, the applications of bacteriology in surgery, hygiene, agriculture, and the preservation or improvement of food; the application of "protozoology" to the study of such diseases as pébrine in silkworms and sleeping-sickness in man; the influence on medicine of the physiological discovery of internal secretions like those of the thyroid gland and the suprarenals; the study of the whole economy of the sea in

relation to various kinds of fisheries; and the utilization of Mendel's principles of heredity in the practical improvement of domestic animals and cultivated plants.

In his *Wonderful Century* Dr. Alfred Russel Wallace made an interesting comparison between the practically important applications of science in the nineteenth century and those in all preceding centuries. Among new departures of the nineteenth century he reckoned thirteen as of first importance, namely—railways, steam-navigation, electric telegraphs, the telephone, friction matches, gas lighting, electric lighting, photography, the phonograph, Röntgen rays, spectrum analysis, the use of anæsthetics, and the use of antiseptics. In all preceding time he reckoned only five inventions of the first rank—the telescope, the printing press, the mariner's compass, Arabic numerals, and alphabetical writing, to which may be added the steam-engine and the barometer, "making seven in all, as against thirteen in one single century." Perhaps this estimate was a little more generous to the nineteenth century than to those before it, but it is certainly fair enough to bring out in a very interesting way the concomitance of the progress of science and practically important inventions.

Danger of Utilitarian Criteria.—The list of practical benefits which Science has con-

ferred on man might be greatly lengthened, but what we have given is perhaps sufficiently representative, and there is much risk of over-emphasizing the utilitarian criteria. The too intensely practical man has got so accustomed to the fruits of Science that he is apt to forget that these cannot be forthcoming if the roots die. Therefore to the critic who growls over the time spent on studying sea-weeds, when "what we want is more wheat," over embryological research instead of fish-hatching, over the theoretical puzzles of geology instead of the search for more coal and iron, we must answer, first, that man does not live by bread alone; second, that he must be patient if his desired practical results are to be sure; third, that Science is a unity, and the theoretical foundation is essential if there is to be progressive practical application; and, fourth, that, as a matter of fact, it has often been from the most unpromising theoretical investigations that great practical discoveries have come. Even for the sake of practice, Science should never submit to the over-practical man's canon which makes immediate utility a stringent criterion of worthiness.

To-day, as much as ever, when the enthusiasm for "practical results" is so strong, we do well to remember the distinction drawn by Bacon, nearly four hundred years ago, between those

results of Science which are light-giving (lucifera) and those which are of direct practical utility (fructifera). Regarding which, he came to the memorable conclusion: "Just as the vision of light itself is something more excellent and beautiful than its manifold use, so without doubt the contemplation of things as they are, without superstition or imposture, without error or confusion, is in itself a nobler thing than a whole harvest of inventions." It is an intolerable narrow-mindedness which supposes that a science can be judged only by its practical fruits and not also by its virtue of illumination.

Fundamental Value of "Theoretical Science."—This little book will not have been written in vain if it contributes to expose the pernicious fallacy, which has deceived many, that science can be pruned of its theoretical developments and yet continue to bear fruit. It is supposed by the ignorant that these "efflorescences" could be dispensed with—mere luxuries of the intelligence, and out of place in a utilitarian age. The fact is that they are the blossoms, which in part become fruits.

One of the deleterious results of the fallacy is that it has suggested to students and directors of studies—at all levels—the mistaken policy of trying to secure a "technical education" without an adequately substantial scientific training.

Perhaps this is a Nemesis on the heels of ultra-academic curricula which might have been orientated in relation to practical professional problems without any loss in the thoroughness or all-roundness of the scientific discipline; but the recoil is resulting in a technician who is insufficiently grounded in the principles.

Students of Science have indeed primarily to do with the kind of investigation whose results Bacon called *lucifera*, but our point is that this is the surest, and sometimes even the shortest road to that other kind of result which he called *fructifera*. In one of his lectures Prof. Karl Pearson makes the following impressive statement of his own experience: "I have been engaged for sixteen years in helping to train engineers, and those of my old pupils who are now coming to the front in life are not those who stuck to facts and formulæ, and sought only for what they thought would be 'useful to them in their profession.' On the contrary, the lads who paid attention to method, who thought more of proofs than of formulæ, who accepted even the specialized branches of their training as a means of developing habits of observation rather than of collecting 'useful facts,' these lads have developed into men who are succeeding in life. And the reason of this seems to me, when considering their individual cases, to be that they could adapt

themselves to an environment more or less different from that of the existing profession; they could go beyond its processes, its formulæ, and its facts, and develop new ones. Their knowledge of method and their powers of observation enabled them to supply new needs, to answer to the call when there was a demand, not for old knowledge, but for trained brains." . . . "The only sort of technical education the nation ought to trouble about is teaching people to see and think." . . . "What we want are trained brains, scouts in all fields, and not a knowledge of facts and processes crammed into a wider range of untrained minds." It comes to this: that, on the whole, the deeper and more difficult studies, which stretch our brains most, are of much more value, even technically, than what are called "useful facts."

In an interesting address on "The Debt of the World to Pure Science," Prof. J. J. Stephenson points out that the fundamental importance of abstruse research receives too little consideration in our time, except, of course, from those who really know. The practical side of life is all-absorbent; and it is forgotten that "the foundation of industrial advance was laid by workers in pure science, for the most part ignorant of utility and caring little about it." . . . "The investigator takes the first step and makes the

inventor possible. Thereafter, the inventor's work aids the investigator in making new discoveries to be utilized in their turn."

It is quite plain from the history of Science that the practical value of Science is in direct proportion to the precision of scientific methods, and that the most "theoretical" investigations have often had practical results of extraordinary magnitude. It is not merely that the theory forms the foundations of the Science, there is another reason. Scientific descriptions increase in value as they become absolutely impersonal, as they become perfectly precise, and especially as they become condensed general formulæ which will be applicable to an infinite variety of particular situations. There is no doubt that the quiet thinkers in the scientific cloisters are, like the poets, the makers and shakers of the world.

Historical Illustrations.—Only the extremely ignorant can question the utility of, let us say, the prolonged application of Greek intellect to the laws of conic sections. Whether we think of bridges or of projectiles, of the curves of ships or of the rules of navigation, we must think of conic sections. The rules of navigation, for instance, are in part based on astronomy. Kepler's Laws are foundation-stones of that science, but Kepler discovered that Mars moves in an ellipse round the sun in one of the foci by

a deduction from conic sections. As Laplace said, "Without the speculations of the Greeks on the curves formed from the section of a cone by a plane, these beautiful laws might have been still unknown." Yet the historical fact is that these conic sections were studied as an abstract science for eighteen centuries before they came to be of their highest use.

Those who doubt the value of "theoretical researches" should study Pasteur's life and observe how his services to mankind were based on inquiries which seemed at first sight remote from human application. It is true that Pasteur may be interpreted as the master-peasant, and the tanner's son (see *Evolution*, p. 224), but this need not keep us from recognizing that his researches form an intellectual chain, the first link of which was a study of the crystalline forms of tartrates. Thus, justly, the list of his achievements, recorded around his tomb, begins with "Molecular dissymmetry, 1848," an almost diagrammatically theoretical beginning for a series of researches which have had such a deep and extensive influence on the life of Man.

The twitching of the legs of Galvani's frogs was studied as a theoretical curiosity; who could have foretold that it pointed to telegraphy? It was not for practical purposes that William Smith plodded afoot over England, neither rest-

ing nor hurrying in his exploration of the strata, but how much of the exploitation of our country's mineral resources had its origin in his maps? The important method of spectrum analysis had its beginning in some apparently insignificant observations. Who can say that the early steps which led to finding a cave of treasures (not altogether without alloy) in coal-tar had, to begin with, any practical outlook?

From an address on Technical Chemistry, by Prof. C. E. Munroe, we take another striking case. "The experience of the past has repeatedly demonstrated the commercial possibilities that are latent in scientific theories. A famous example is found in the commercial development of benzene. Lachman, in 1898, after referring to its discovery by Faraday in 1825, and its production from benzoic acid by Mitscherlich nine years later, says: 'These famous chemists little thought that their limpid oil would one day lay claim to be the most important substance in organic chemistry; that it would give birth to untold thousands of compounds; that it would revolutionize science and technology. The technical development of benzene and its derivatives employs over fifteen thousand workmen in Germany alone; the commercial value of the products reaches tens of millions of dollars. . . . *Nearly all of this tremendous activity is due to a*

single idea, advanced in a masterly treatise by Auguste Kekulé in the year 1865.'"

It is a commonplace that the developments of steam-power, electric Telegraphy, Telephony, and Dynamo-electrical machinery, which have changed human life so markedly, have come about in association with new *theoretical* developments in the sciences of heat and electricity. To substantiate this precisely is not difficult, but an analogous case will, we think, suffice for demonstration. When Prof. William Thomson published, in 1853, in the *Philosophical Magazine*, a stiff bit of mathematical analysis, which laid the foundation of the theory of electric oscillations, there can have been few who saw in it *the basis of wireless telegraphy.*

In this connection, it is very interesting to hear Lord Kelvin's own opinion, for he excelled alike in theoretical insight and in practical application. After speaking of "the vast resources which we derive from direct applications of modern science," "of the immense practical importance of the principles of Natural Philosophy," he says: "We must not, however, by considerations of this kind, be led to regard applications to the ordinary purposes of life as the proper object and end of science. Nothing could more effectually stop the advancement of knowledge than the prevalence of such views; even the

desired *practically useful* discoveries would not be made if researches obnoxious to the fatal question *cui bono* were to be uniformly avoided. . . . Oersted would never have made his great discovery of the action of galvanic currents on magnets had he stopped in his researches to consider in what manner they could possibly be turned to practical account; and so we should not now be able to boast of the wonders done by the electric telegraph. Indeed, no great law in Natural Philosophy has ever been discovered *for* its practical applications, but the instances are innumerable of investigations apparently quite *useless*, in this narrow sense of the word, which have led to the most valuable results."

Dr. A. E. Shipley has recently called attention to two diagrammatic illustrations of our theme. "A few years ago no knowledge could seem more useless to the practical man, no search more futile than that which sought to distinguish between one species of gnat or tick and another; yet that knowledge has rendered it possible to open up Africa and to cut the Panama Canal. This witness," Mr. F. A. Dixey remarks, "is true; and it would be difficult to point to a more complete demonstration of the fact that natural knowledge, pursued for its own sake, without any direct view to future utility, will often lead to results of the most unexpected kind and of

the very highest practical importance" (*Nature*, Sept. 2, 1909).

We see, then, that undue insistence on the practical utility of science is not historically justified, and that hasty criticism of lines of scientific work as purely theoretical is likely to be very unjust. What practical result may flow from an apparently abstruse and detached investigation no one is wise enough to predict, and inventions usually rest on a patiently established theoretical basis. Minerva-like birth of discoveries is rare. As Prof. Stephenson puts it: "Discoveries which prove all-important in secondary results do not burst forth full grown; they are, so to say, the crown of a structure raised painfully and noiselessly by men indifferent to this world's affairs, caring little for fame and even less for wealth. Facts are gathered, principles are discovered, each falling into its own place until at last the brilliant crown shines out, and the world thinks it sees a miracle."

The ultra-practical man's impatient "What's the use of it?" may be occasionally a sound corrective, since science, as well as art, requires to be socialized. But it often reveals an intellectual shortsightedness. As Sir Lyon Playfair once said: "Truer relations of science to industry are implied in Greek mythology. Vulcan, the god of industry, wooed science, in the form of

Minerva, with a passionate love, but the chaste goddess never married. Yet she conferred upon mankind nearly as many arts as Prometheus."

Socialized Science.—But how does the idea of science for its own sake harmonize with that expressed in Spencer's sentence: "Science is for Life, not Life for Science"? There is no antithesis.

1. Science is certainly for the development of life, but "life" must not be conceived of narrowly. "Is not the life more than meat, and the body than raiment?"

2. Moreover, for educated men in modern civilized communities, life must be to some extent for science, if it is to have any degree of completeness.

3. Our point has been that Science will do best for the citizen if it is left to attend to its own business.

On the other hand, while we may not be able to say of any specialized line of scientific inquiry that it is not of value to human life, there are some which are more promising and urgent than others. Many kinds of quantitative descriptive work, which afford very enjoyable occupation to naturalists and very useful disciplining material for apprentices, are not particularly urgent. And eventually we must admit that men of science are the intellectual advisers and educators of the great mass of humanity who are concerned with

the fundamental problem of bread and butter, with the science known as "Brodwissenschaft."

Therefore, since scientific investigators are as liable to preoccupation as other men, it is well that prominence should be given to the humane ideal of socialized science. Bacon got at it long ago in the description which he gives of the true spirit of the scientific investigator in a famous passage in the *Advancement of Learning:* "This is that which will indeed dignify and exalt knowledge if contemplation and action be more nearly and straitly conjoined and united together than they have been; for men have entered into a desire of learning and knowledge, sometimes upon a natural curiosity and inquisitive appetite; sometimes to entertain their minds with variety and delight; sometimes for ornament and reputation; and sometimes to enable them to victory of wit and contradiction; and most times for lucre and profession; and seldom sincerely to give a true account of their gift of reason to the benefit of man; as if there were sought in knowledge a couch whereupon to repose a searching and restless spirit; or a tarasse for a wandering and variable mind to walk up and down with a fair prospect; or a tower of state for a proud mind to raise itself upon; or a fort or commanding ground for strife and contention; or a shop for profit or sale; and not a rich storehouse for

the glory of the Creator and the relief of man's estate."

But there are two sides to this idea of socialization, the other being the duty of the State to utilize the resources of Science in the solution of practical problems. Whether we think of the more effective and less wasteful exploitation of the Earth, or of the gathering in of the harvest of the sea, or of making occupations more wholesome, or of beautifying human surroundings, or of exterminating infectious diseases, or of improving the physique of the race—we are filled with amazement at the abundance of expert knowledge of priceless value which is *not* being utilized.

As to what may be called the moralization of Science—this is a subject on which only the high priests in the temple should speak, and we shall not do more than recall the noble words of one of these. Helmholtz writes: "As the highest motive influencing my work—though not reached in my early years—was the thought of the civilized world as a constantly developing and living whole, whose life, in comparison with that of the individual, appears as eternal. In the service of this eternal humanity my contribution to knowledge, small as it was, appeared in the light of a holy service, and the worker himself feels bound by affection to the whole human race, and his work is thereby sanctified. This feeling all can

theoretically understand, but long experience of it alone can develop it into a powerful and steady impulse."

In this chapter we have used the word utility in the sense of practical utility, having in other chapters said enough to show that Science can justify itself, if necessary, at a higher court of appeal. For Science is a natural and necessary development and discipline of Man; it supplies stimulus and raw material to literature and art; and it has contributed to the store of great ideas which should always be in the saddle and should always rule mankind.

SUMMARY.—*Science is justified for its own sake as a natural and necessary human activity. It has grown out of practical lore and always receives fresh stimulus by coming back to practical problems. One of the great conditions of human progress is the unceasing reciprocal relationship between science and occupation. The practical utility of the sciences is so great that there is danger in exaggerating utilitarian criteria. Nothing is more certain than the fundamental value of "theoretical science." But while the greatest practical gains have come from the prosecution of "pure science," it may be agreed that Science should be socialized, for, after all, Science is for Life, not Life for Science. As Comte said, "Knowledge is Foresight, and Foresight is Power."*

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